No. 1. — *The Palolo Worm, Eunice viridis* (*Gray*).

By W. McM. Woodworth.

The Palolo worm[1] first became known from the Samoan Islands, where it attracted the attention of the missionaries because it was eaten, prized and sought for by the natives, and because it appeared periodically in certain localities in enormous numbers, and for a few hours only, and because it made its appearance almost invariably in the months of October and November, and always during a quartering of the moon, and was not seen again until the following year under precisely the same conditions. It further became known that the November crop was vastly larger than that of October, and that *all* "Palolo" were *headless*.

The earliest published description of the "Palolo" is that by J. E. Gray (**1847**), based on material sent to the British Museum by the Rev. J. B. Stair, a missionary in the Samoan Islands. Gray placed it near to the Arenicolidae and gave it the name *Palola viridis*. It was figured by Macdonald (**1858**), and although his figures are most accurate, the so-called head is that of a Lysidice, as was pointed out by Ehlers (**1868**), who renamed it *Lysidice viridis*. The first extended account was written by Collin (**1897**) as an appendix to Krämer's earlier work on Samoa. Collin, with previous writers, considered the "Palolo" to be the posterior part of a Lysidice, a few heads of which had, from time to time, been taken with the "Palolo" at the 'fishing' season, and as no other annelid heads were taken, and all "Palolo" were headless, it was natural, for want of better evidence, to ascribe the "Palolo" to the genus Lysidice.[2] For thirty years it was ascribed to that genus, and Macdonald's

[1] In the Fijian Islands the worm is called "Bololo," pronounced Mbololo by the natives. In the course of the present paper I shall use the Samoan name Palolo, for it was in the Samoan Islands that it was first heard from and its true history became known. When the name is printed "Palolo," *i. e.* in quotation marks, I refer to the headless, epitokal, free-swimming portion of the worm. Different writers have spelled it Pulolo and Palola. It has also been called the "Fiji Worm."

[2] Quartrefages (**1858**) calls it *Lysidice palola*.

figures were the only ones,[1] and were often copied. In 1898 Friedlaender (**1898**) figured the head of what he recognized to be that of a Eunice. This, with other material, he obtained from the reef-rock at Samatau in Samoa. His material was afterwards studied by Ehlers, who (**1898**) showed that Friedlaender had found the real head of the "Palolo," which then became *Eunice viridis* (Gray).

It was my good fortune, while acting as assistant to Mr. Alexander Agassiz in the Fiji Islands, to be present at the annual 'rising' of the "Palolo" (Mbololo) at Levuka on November 17th 1897, and Mr. Agassiz has (**1899**, p. 16) given an account of our experiences at that time. In the following year Mr. Agassiz dispatched me to Samoa to be on hand for the November appearance of the "Palolo" and to search the reef-rock for the entire animal. On my arrival at Apia I was fortunate in finding Dr. Krämer, who placed his notes at my disposal as well as all of the annelid material he had collected from the reefs in his search for the Palolo head. I am also under obligations to Mr. W. Blacklock, U. S. Vice Consul at Apia, to Captain Victor Schoenfelder of H. I. M. S. "Falke," to my friend C. L. Crehore who accompanied me to Samoa, and to Tui Malealiifanu, the head chief of Falelatai where I made my headquarters.

After searching the reefs to the westward, at Samatau, where Friedlaender obtained his material, for several days without result, the natives took me to a small bay called Fagaiofu to the eastward of Falelatai. The bay lies between two small promontories which are about one quarter of a mile apart, and is almost filled with a fringing reef, the sea edge of which is not more than two hundred feet from the beach at extreme low tide. Small patches of dead coral occur almost at the beach line, becoming larger and more numerous seawards, where they are more or less confluent so as to make a kind of platform. This general platform is interrupted by two deep narrow channels or passages corresponding to the outlets of small streams. At extreme low tide, that is at neap tide, the place is so shallow that one can wade from the shore to the outer edge of the reef platform. The reef at Fagaiofu is composed of dead coral and the usual honeycombed reef-rock, except at the outer edge where there is living coral. By prizing off masses of the rock with a crowbar at the edges of the deeper channels, "Palolo" were disclosed in great numbers and could be seen dangling from the freshly exposed surfaces, and wriggling free into the water to be

[1] McIntosh (**1885**) figured some chætae from material obtained by the "Challenger."

carried seaward by the retreating tide. This was about one hour before dead low water, and just before sunset on November third, two days before the "Palolo" was expected. Masses of the rock were taken back to Falelatai and by means of chisels, forceps, and lamplight, one specimen was obtained complete. The next day, the eve of the expected 'rising', we again went to Fagaiofu to camp for the night, and at low water obtained more material, including three complete specimens. Owing to the great length of the worm and its intricate association with the reef-rock the operation demands patience and delicate handling. It is in the galleries and cavities of the reef-rock that the Palolo has its abode. They were found everywhere on the reef and could be exposed by breaking open the surface, but more easily at the edges of the deeper places. Plate **3** shows, in natural size, a piece of the reef-rock presenting a top view and an end view showing the fractured surface. Fagaiofu is not easy of access, and a boat can land only when there is enough water over the reef. The platform can be worked only at extreme low tides which, in the Palolo season, are the neap tides, and occur about sundown and sunrise. This season is also the rainy season. Stair was present at the "Palolo" 'rising' at Fagaiofu in 1847 and (**1897**), speaks of it as "one of the famous fishing places." It is strange that I should have been the first to visit the place since his time, and almost by accident, and by only a narrow margin of time. The place is an ideal one for the study of the Palolo, if one could be there during some weeks covering the time of its swarming.

I must speak, as briefly as possible, of the petty discussion which appeared between 1898 and 1903 as to whom belongs the credit of first discovering the real head of the "Palolo." In March, 1898, Friedlaender (**1898**) states that the meaning of the Palolo phenomenon was simultaneously discovered by Krämer, Thilenius, and himself.[1] In May of the same year, Friedlaender (**1898**[a]) says that the nature of the Palolo was discovered simultaneously by Thilenius and himself, and later (**1904**), it reads that he alone, and possibly Thilenius, made the discovery. In this paper he quotes me as saying (**1903**) that it was through Krämer's investigations that the true history of the Palolo became known. I refer Dr. Friedlaender to the English edition of my preliminary paper (**1903**[a]) which was translated for Krämer's "Die Samoa Inseln," though not published until a few months later, to see that I was not unfair to him, as he charges. The discovery of the origin of the

[1] In his subsequent publications he makes no mention of this paper, but speaks (**1904**) of his second paper (**1898**[a]) as "meine erste Abhandlung."

"Palolo" was made independently by Krämer and Friedlaender, although the latter was the first to publish an account of his investigations. Friedlaender succeeded in obtaining from the reef-rock at Samatau several specimens of "Palolo," together with the head ends of an annelid of different appearance and much larger size belonging to the genus Eunice. Friedlaender was the pioneer, for he was the first to identify the large head-end as that of a Eunice, and was the first to figure it as well as the transition piece between it and the "Palolo," and it was from his material that Ehlers gave us the final name *Eunice viridis* (Gray). All that I can hope to do is to establish, beyond doubt, the origin of the "Palolo," and confirm the researches of Friedlaender and Krämer, and add something to our knowledge of the morphology, habits, and relationships of this once mysterious worm.

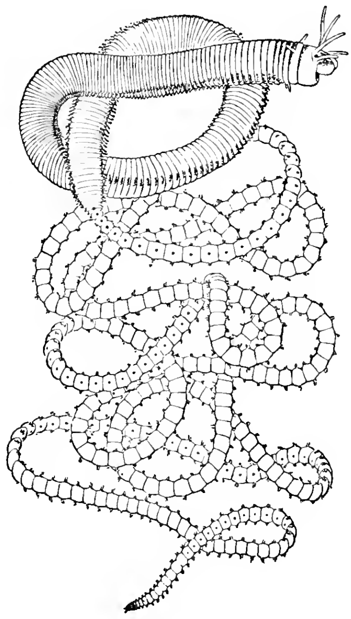

FIGURE 1.

Eunice viridis (Gray). The narrower posterior, epitokal part, when detached and free-swimming, is known as the "Palolo." About natural size.

It was Ehlers (**1898**) who first gave a detailed description of the Palolo worm and recognized an extreme case of sexual dimorphism, and showed the "Palolo" to be the epitokal posterior portion of *Eunice viridis* (Gray). He says (**1898**), "Ich ergänze das im Voraus damit, dass ich die Eunice, die nun den Namen *Eunice viridis* (Gray) erhält, in den Kreis der *Eunice siciliensis* Gr. bringe und an ihr die Ausbildung des "Palolo" als eine Form der Epitokie auffasse, wie sie zum ersten Male aus der Familie der Euniciden, und in ihrer Besonderheit abweichend von allen Erscheinungen der Epitokie, die von Borstenwürmern bekannt sind, sich darstellt. Demnach ist in der Art eine atoke und epitoke Form, in der letzteren eine atoke und epitoke Körperstrecke zu unterscheiden." We have then in the Palolo, combined in the same individual, an atokal and an epitokal part corresponding to the anterior and posterior ends of the animal (Text Fig. 1), and it is the posterior epitokal

part, the "Palolo," that is periodically cast off and leads such an ephemeral existence, while the anterior atokal part remains in the galleries of the reef-rock to regenerate, by a process of strobilization, a new posterior atokal sperm or egg sac, which at the appointed time is again set free. The sexes are different in color, the color of the male being reddish brown or buff to yellowish, while that of the female is a deep bluish green (Figs. 1 and 2). These colors are very pronounced in the epitokal region, and are due to the sexual elements, ova and sperm. After the discharge of the sexual elements the collapsed integument is colorless and translucent. These distinctive sexual colors are found in the broader anterior atokal region, but not in so marked a degree, the female being only a little more greenish in color than the male, and here the colors are doubtless integumentary (Fig. 3). It is from the deep green color of the ova in the epitokal region that the specific name *viridis* is derived. Ehlers (**1898**) has so minutely and accurately described the worm that it would be superflous for me to quote at length the details written by the master's hand, and I refer the reader to his paper. I can only supplement his description by additional measurements, etc., from more abundant material, and supply some figures.

The length of the "Palolo," that is the free-swimming epitokal part of the worm, has been variously estimated at from a few inches to three feet, *i. e.*, a maximum of 90 cm. This great length is given by Gill (**1854**). The longest specimen that I measured in the living condition was 30 cm. This is about the average of the measurements given by seven authors. From alcoholic material, where there is considerable shrinkage, Ehlers estimated 20 cm, and states that some segments were probably missing. The atokal region comprises about one fourth of the total length of the worm, and the greatest diameter is about 4 mm, while the length of the segments is about ½ mm, or about twenty times as broad as they are long. This ratio begins at about the fifteenth segment from the anterior end, not counting the two large cephalic segments (Fig. 3). The ratio of length to breadth of these fifteen segments is about five to one. In the first of the two large cephalic segments the ratio is about two to one, and in the second four to one (Figs. 3 and 7). The broader anterior segments are also marked by a brown pigment which is densest on the dorsal surface, diminishing toward the sides and disappearing toward the ventral surface. It is densest in the two large cephalic segments diminishing posteriorly, and ceases at about the fifteenth segment, where they become shortest (Fig. 3). In one male specimen 429 atokal segments were counted, in another 350. These

counts are not accurate owing to a dense gelatinous secretion in the posterior part, which makes it difficult to count the very short segments. The region of this secretion, in the longest of the atokal specimens, began at about segment 300 and extended backward to the narrow epitokal region. The transition between the broad atokal and attenuated epitokal regions is abrupt and very marked (Text Fig. 1 and Fig. 10, Plate 2), owing to the difference in diameter and shape of the segments and the difference in color due to the sexual elements in the epitokal segments. The diameter of the epitokal segments is, in general, slightly more than 1.50 mm in alcoholic material, and the length is about the same. In the living animal the length of the segments is slightly more than the breadth. The epitokal region has somewhat the appearance of a string of beads, the segments being rounded, bulging at the middle and constricted at the dissepimental zones (Text Fig. 1). As has already been mentioned, the epitokal region is but an egg or sperm sac and leads but a brief free existence, and as will be seen later, the rounded, plump shape of the segments can be explained by the suppression of organs due to the crowding effect of the sexual products. Beginning at about the fifteenth from the posterior end, the segments become narrower and more flattened so that the posterior end tapers to the last or anal segment. Varying from two to fifteen in number, the preanal segments are colorless and translucent, not containing any sexual elements (Fig. 9). The cephalic and anal cirri (Figs. 3 and 9), the chætae (Figs. 13 and 14) and the jaw apparatus (Figs. 11 and 12), are characteristic of the genus, and have been minutely described by Ehlers. The great length of the cirri on the first pair of parapodia described by him is plainly seen in Figure 3. Ehlers finds many resemblances between *Eunice viridis* and *E. siciliensis* Gr. in which species there is also, at sexual maturity, an intensification of the color in the posterior region. With Ehlers, I found the gill filaments in the atokal region to begin at about the 135th segment. They attain their greatest length at about segment 175. The presence of gill filaments in the epitokal part is difficult to determine. When they are present they are much aborted, and there is no particular region where they can always be found. They are constantly absent in the empty, translucent, preanal segments. Ehlers believes that where the gill filaments are lacking in the epitokal region they have been lost, "abgefallen," due to their slight union with the dorsal cirrus, and that the loss of them may be due to one of the regular processes involved in the life of the "Palolo." This is in accord with other processes that take place, such as the general histol-

ysis of internal organs to make room, as it were, for the accumulation of sexual products, and the reduction in the number of chætae in the parapodia, processes adapted to its function and brief existence; while the life of the atokal, parent-end is, as far as known, perennial. The general shape of the parapodia in the atokal and epitokal regions is the same; those of the anterior region being perhaps somewhat broader, and containing a larger bundle of chætae, both simple and compound. In the epitokal region I found usually, even as far back as the thirteenth preanal segment, two of the simple, dorsal chætae and three of the ventral compound ones (Fig. 13), while Ehlers says, "ist häufig nur eine einfache und eine zusammengesetzte Borste vorhanden." A reduction of organs and histolysis of tissues in epitokal forms of annedids has been noted by Ehlers (**1868**) in Glycera, Caullery and Mesnil (**1898**) in Dodecaria, by Claparède (**1870**) in Polyopthalmus and Pædophylax, Eisig (**1887**) in Notomastus, etc., and McIntosh (**1885**) has spoken of it in the "Palolo." The intestine is reduced to a thin flattened ribbon, and the segmental organs are difficult to determine, more especially so in the female. Also there is a great reduction in the thickness of the body wall, a condition that exists in other annelids at sexual maturity.

All sexual products, according to Powell (**1883**), are discharged through "oviducts and seminal ducts," and Ehlers believes, with Powell, that the sexual products are discharged by means of "ausführende Apparate." My observations do not agree with this. In Fiji I isolated single individuals in separate vessels and observed the discharge of the sexual products, which was best seen in females on account of the large size and deep color of the ova. In one instance, a female of about ten inches in length, the ova were discharged as if simultaneously from all segments, leaving a small mass of shriveled translucent pellicle. It seemed incredible that so large a worm could be suddenly reduced to so small a mass. The process was like an explosion, and the ova must have been under great tension. When a few specimens were kept in the same vessel, the number of heaps of green granules at the bottom of the vessel indicated the number of females that had discharged their ova. On examination of the collapsed integument, distinct lateral rents or tears could be seen, and could, in some cases, be traced confluent through several segments. The large size of the ova, 14.5 μ in diameter, would preclude any rapid discharge by means of segmental organs. On the other hand I believe that some of the male elements may find their way out through the segmental organs as they can be demonstrated there in sections, yet living males "explode" in the same

way as females. Eisig (**1887**) describes similar conditions in Notomastus, where the sexual elements are discharged by rupture of the body-wall, and states that the lumen of the segmental organs is too small for the passage of ova. Mayer (**1900**), for his "Atlantic Palolo," says that by series of violent and sudden contractions "the ripe segments are torn asunder at short intervals by the breaking of the cuticula, forming large rents through which the genital products escape." This manner of unloading the sexual products accounts for the apparent sudden disappearance of the dense swarms of "Palolo" a short time after their appearance, which was considered as much of a phenomenon as their sudden appearance.

Each segment of the atokal part bears on its ventral surface a prominent circular pigmented spot, deep brown or black in color (Text Fig. 1, Figs. 9 and 10, plate **2**). They can be traced forward into the atokal region through about twenty segments, though much reduced in size, and paler in color (Fig. 10). They are absent in from two to fifteen of the preanal segments, those colorless, translucent segments that contain no sexual elements. They were first noted by Ehlers (**1868**) who likened them to eyes in appearance, but looked upon them as the external openings of some sort of a longitudinal gland. It was Spengel (**1881**) who first estimated their true nature, and speaks of them as "wirkliche Augen." The minute structure of these ventral eye-spots was studied by Hesse (**1899**) in carefully prepared material collected by Krämer. Although he states that it is improbable that they are capable of forming images, he says: "Es wird also ihre Leistungsfähigkeit auf die Unterscheidung verschiedener Lichtsintensitäten, vielleicht auch von Farben, und auf das Erkennen der Lichtsrichtung beschränkt sein." Schroeder (**1905**), who also made an histological study of these eye-spots, asserts that they differ so much in structure from all known eyes that it is not possible to compare them with any. He hints at the possibility of their being light-producing organs. If they were phosphorescent organs it would have been noted long ago, and could not have escaped the eyes of the natives, as the "Palolo" appears in dense swarms at the surface of the water, and in deep darkness. It is significant that these eye-spots occur in a rudimentary form on only a few of the posterior segments of the atokal, sedentary, part of the worm, and are so highly developed on all but a few of the segments of the active, epitokal part. I believe with Hesse that they react in some way to light, or possibly to heat rays. In text Figure 2, I reproduce Hesse's figure of a median section of one of these eyes, which plainly shows their structure.

On the day before the 'rising' of the "Palolo" (the *motusaga* day of the natives, see *infra*), a small annelid, headless like it, and the sexes also distinguished by brown and greenish tints, makes its appearance in large numbers. It is this small worm that in my preliminary paper (1903) I ascribed to *Lysidice falax*, the name that Ehlers gave to the Lysidice-head figured by Macdonald, and for so long believed to be the

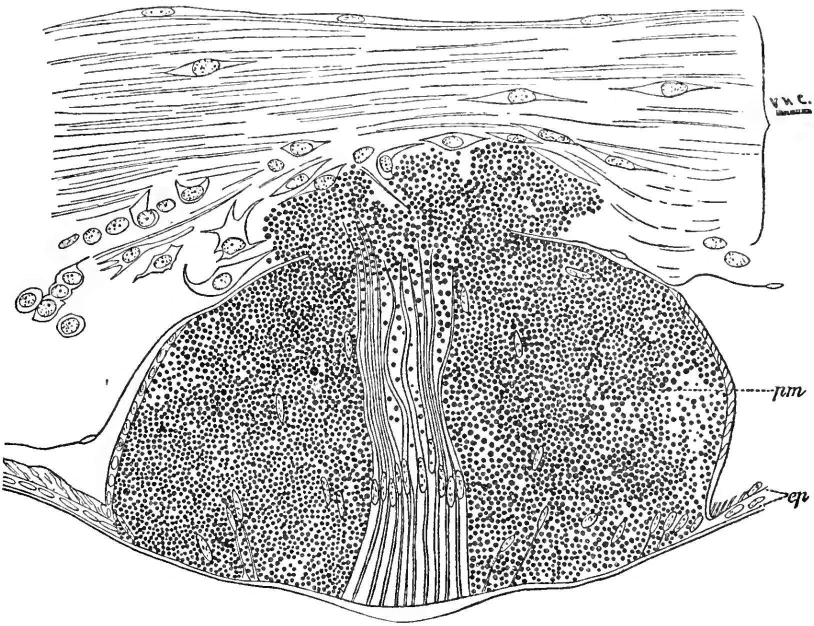

FIGURE 2.

Longitudinal medium section of one of the ventral eye-spots of the "Palolo." After Hesse. × 400. *v. n. c.*, ventral nerve-cord ; *p. m.*, pigment mass ; *ep.*, epithelium.

real head of the "Palolo." This small headless worm, a diminutive "Palolo," does not belong to *L. falax*. I have complete specimens of the latter which in no way exhibit any heteramorphosis or differentiation between the anterior and posterior regions. A description of *L. falax* is reserved for a subsequent paper on Eunicidae from the reefs of the Pacific Islands. To the little "Palolo" of *motusaga* day I give the tentative name *Eunice dubia*. The segments have the same general shape as those of the "Palolo" and measure, in alcoholic material, about 0.75 mm; in diameter, being slightly shorter than broad (Figs. 4 and 5). As

in *E. viridis* about twelve of the preanal segments are colorless and translucent, not containing any sexual elements. These empty segments are usually much wider than those preceding them, thus marking off a distinct broader preanal region (Fig. 5). The longest specimen measured 3 cm, from the material collected by Krämer at Apia. Usually there is present, in each segment, a pair of brownish or blackish pigmented spots at the dorsal base of the parapodia (Fig. 6). These are not comparable to the ventral eye-spots of *E. viridis*, but rather to the paired pigmented "glands" so common in the Alciopina and Tomopteridae and, possibly, have a photogenic function. Treadwell (**1900**) has described similar paired organs in *E. armata*. The composition of the parapodia (Fig. 15) is much simpler than in *E. viridis*. There are two of the simple chætae, one much longer than the other, and but one of the compound kind. The figure does not show the cirri which are much shorter than in *E. viridis*, and gill filaments could not be determined; the figure is inverted.

The first detailed account of sexual dimorphism in annelids is by Alexander Agassiz (**1862**) for Autolytus, and Malaquin (**1893**), has called attention to its occurrence in other Syllidae. In the Nereidae, sexual dimorphism was first described by Ehlers (**1868**) where it is known for upwards of twenty species, and it is manifested in different ways pretty much throughout the Annelida. It occurs in two general ways. First, as in the Nereidae, where certain sexual individuals undergo a metamorphosis adapting them for the dissemination of the sexual products (Heteronereis), and secondly as in the Eunicidae ("Palolo"), where certain regions of the animal, containing the sexual elements, become modified and are set free by a process of autotomy. In the first case the metamorphosed individuals are known as the epitokal (Ehlers, **1868**) or epigamous (Claparède, **1870**) forms, in the latter the sexually modified part which is set free is the epitokal part of the animal, the unmodified part, the parent animal, which may or may not regenerate the liberated portion, is the atokal part. In the latter class it is usually the posterior portion that is set free as in *Eunice viridis, E. fucata* (Mayer, **1900**, **1902**) Syllidae, etc., while in *Ceratocephale osawai* (Izuka, **1903**), one of the Nereidae, it is the anterior region that leads a free existence. In most epitokal forms there is a great development of the eyes. In the Nereidae, the active epitokal form is attracted by artificial light, and Izuka (**1903**), states for Ceratocephale that the fishermen attract them by the light of torches, catching them for bait. I have observed the same attraction to artificial light in several forms of Heteronereis. This development of the eyes in epitokal phases of annelids is significant, and as I have pointed

out the ventral eye-spots are fully developed only in the posterior free-swimming part of the Palolo.

According to Riggenbach (**1902**) autotomy (Selbstverstümmlung) in annelids is brought about through external stimuli, and the parent atokal part of the Palolo may be looked upon as a sexual nurse or stock which regenerates the epitokal region, a process comparable to strobilization in cestodes. Brunelli and Schoener (**1905**), who name this process schizoepitokie, call attention to the fact that the most complicated reproductive processes in annelids exist in those forms that inhabit shores and reefs, are simpler in pelagic forms, still less complicated in fresh water forms, and simplest of all in terrestial forms. In the phenomenon of the periodic appearance of the "Palolo" they believe that inorganic forces have played the most important part in establishing reproductive autotomy, and since annelids inhabiting reefs and shores are subject to wounds and amputations due to the action of the waves on rock-fragments and sand, and friction between the worm and the rock, etc., epitokie arose from such amputations, which later became simple division and finally adapted to the dissemination of the species, and since these mechanical causes were coincident with certain seasons, such a periodic seasonal mechanical stimulus has played an important role in the ancestral history of the Palolo.

The periodic swarming of the "Palolo" has been ascribed to various stimuli such as light, heat, salinity and pressure of the water, atmospheric electricity, etc. Friedlaender (**1898**), says that a reaction to light has nothing to do with the "Palolo" phenomenon, neither moonlight, which is reflected light, nor the light of dawn, and suggests a negative geotropism through diminished water pressure at low tides. The "Palolo" appears in the months of October and November in the last quartering of the moon. This is the season of neap tides, when the reef flats are uncovered or only awash. At this season the sun is nearest the zenith in southern latitudes, a season when the sun's light and heat is greatest. I believe in some heliotropic or thermotropic reaction of the eye-spots borne on the segments of the epitokal part of the Palolo. A glance at Text Fig. 2, p. 11, showing the structure of one of these ventral eye-spots is more than suggestive that their function is to react in some way to light or heat rays. Friedlaender's contention that the "Palolo" appears in almost absolute darkness does not, to my mind, preclude a reaction of the eye-spots to light or heat, for these influences have been acting for a considerable period of time as there are three distinct days involved in the 'rising' of the "Palolo."

The "Palolo" makes its appearance twice a year and always in a quartering of the moon, at a neap tide in October and November. For Fiji the October rising is known as "Bololo lailai," *i. e.*, small or few "Palolo;" the November one is called "Bololo levu," *i. e.*, large or many "Palolo." The October crop is not large enough to interest the natives in its capture, but marks in a way the time for the appearance of the great November crop.[1] There are various signs known to the natives by which they reckon when to expect the swarming of the worm, such as the distance above the horizon of certain constellations, the "march" to the sea of the land crabs to deposit their eggs, the appearance of certain small fish, the ripening of certain tubers, the flowering of plants, etc. An old Fijian chief told me that you might expect the "Bololo" when in the last quartering of the moon in October and November there is a low tide just before sunrise. This spring season is recognized throughout the Pacific islands, and where the "Palolo" occurs the native calendar bears its mark as to the names of seasons and months. All of the annelids living in the reefs are sexually mature at this time, as shown by the extensive collections made by Krämer and myself, and this is true of the general animal life of the reef. In Samoa this season is known as *taumafamua*, *i. e.*, the time of much to eat. In the Banks Islands, Mota (Codrington, **1891**), the season is called *tau matua*, the season of maturity.[2]

Good accounts of the fishing of the "Palolo" are given by Churchill (**1902**), Churchward (**1887**), Krämer (**1902**), the Earl of Pembroke (**1872**), Seeman (**1862**), Stair (**1897**), Thompson (**1896**), von Werner (**1890**), and others. The 'Palolo-time' embraces three successive days. When in the last quarter of the moon in October and November, more especially the latter, the water on the 'Palolo-grounds' has a turbid or roiled look, with floating patches of scum, the natives know that two days later the "Palolo" will 'rise.' This first day is called *salefu*. The second day is marked by the swarming of a small annelid, headless like the "Palolo," and the sexes distinguished by the same yellow and greenish tints. This day is called *motusaga*. The third is the *tatelega* when the "Palolo" swarms and the natives come many miles to the favoured places to gather it. With "Palolo" of the *tatelega* day many of the small annelids of the *motusaga* occur, and a few "Palolo" appear

[1] I can offer no explanation why there should be two distinct crops and in adjacent months, nor why the November crops should be so much larger.

[2] It is not in the province of this paper to enter into the legends, folk-lore, and ceremonies of the natives with which the "Palolo" has so much to do.

on *motusaga* day. A microscopical examination of the *salefu* scum shows it to consist of a gelatinous slime in which are grains of sand, appendages, fragments and casts of Entomostraca, and a varied detritus of the seething life inhabiting the reefs, including many ova of various kinds in different stages of segmentation. The *salefu* may be looked upon as a manifestation of the awakening of the "Palolo" previous to its swarming or marriage-swim; an annual activity of countless numbers of annelids resulting in a discharge into the water of the deposits accumulated in the galleries and crevices of the reef-flats. The small annelid of *motusaga* day is what I have called *Eunice dubia* (Figs. 4–6, 15) and is doubtless what Friedlaender speaks of as the "Pseudo-palolo." The "Palolo" appears in some localities in such enormous numbers that the surface of the sea has been likened to a thick vermicelli or macaroni soup, and I have seen a native with his bare hands fill a large pail with the worms in a few minutes. In Fiji I have seen the natives testing the water by wetting their hands and smelling it, and in this way detect the presence of the worm before it had been seen. I was unable to learn of this method in Samoa. The "Palolo" is eaten raw, but more usually baked in leaves of the breadfruit or boiled. The mass resembles cooked spinach in appearance, the whole taking on the deep green color of the female. In taste and smell it is not unlike fresh fish roe. It is eaten with impunity by both old and young, and in Fiji the water in which it is boiled is sometimes given to the sick.

The "Palolo" is known from Samoa, Fiji, and Tonga. It occurs on all of the larger of the Samoan Islands and throughout the Fiji group. Early records of the time of its appearance in Fiji have been kept at Lakamba from 1845–1854, and at Levuka from 1854–1858. In every case its appearance was in a quartering of the moon, which is true also of Whitmee's records for Savaii in Samoa (1862–1868) and the later records from both groups of islands.

The earliest recorded observations of the swarming of annelids are those of Rumphius (**1705**) for the "Wawo" of Amboina for the years 1684 to 1694. The recent "Siboga" expedition brought back specimens of this worm which were studied by Horst (**1905**) who named it *Lysidice oele* (see also Weber, **1902**). As in the "Palolo" its annual appearance is directly related to a phase of the moon, as it makes its appearance in March and April only on the second and third nights after full moon. This relation of swarming of annelids to phases of the moon is noted by Mayer (**1900** and **1902**) for *Eunice fucata*, and Izuka

(**1903**) for *Ceratocephale osawai*. A similar swarming of marine annelids, and at corresponding seasons, is known for other islands of the Pacific, though the worms have not everywhere been identified. Powell (**1883**) speaks of them in the Gilbert Islands where they are known to the natives as *te nmatamata*, and Codrington (**1891**) gives a detailed account for Mota in the Banks Islands where they are known as *un*. Brown (**1877**) mentions an annual appearance of a "Palolo" on the East coast of New Ireland. That the annelid is best known from Samoa and Fiji is accounted for by these two groups of islands having been most visited and longest inhabited by whites. It is significant also that such records as we possess from other places, though meagre, have come to us through the missionaries, the pioneers of intelligent whites in the islands of the Pacific.

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EXPLANATION OF PLATES.

Figures 1 and 2 were drawn by A. G. Mayer, Figure 3 by M. Westergren, Figures 4 – 10 by J. H. Blake, and Figures 11 – 14 by author.

PLATE 1.

FIGS. 1 and 2. The male and female "Palolo," the epitokal parts of *Eunice viridis* (Gray). Sketches to show the colors of the living animal. About natural size.

FIG. 3. Head end of a female. × 3.

FIGS. 4 and 5. Female and male epitokal parts of *Eunice dubia*, sp. nov. × about 8.

FIG. 6. Two segments of the epitokal part of *E. dubia*, showing the paired pigmented spots at the base of the parapodia. × 35.

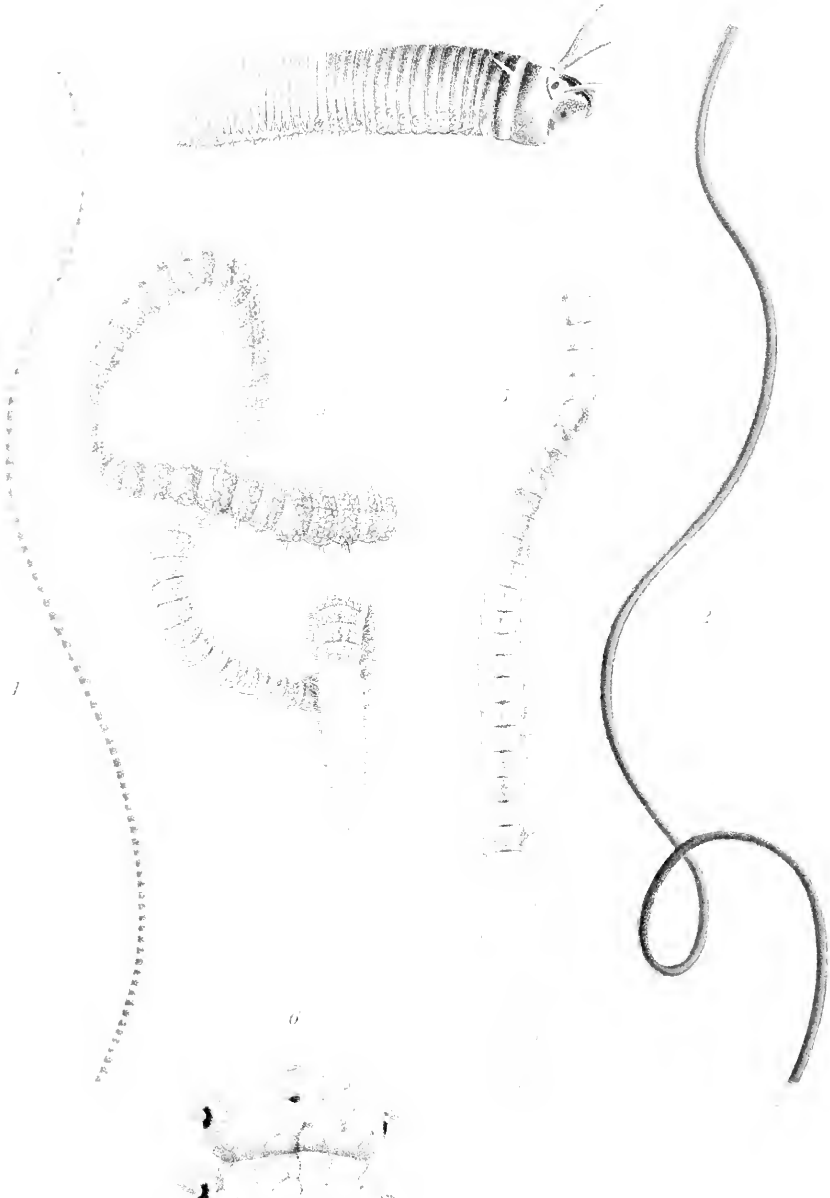


PLATE 2.

Fig. 7. Ventral view of the head end of *E. viridis.* $\times\ 4\frac{1}{2}$.

Fig. 8. Anterior view of the head end of *E. viridis.* $\times\ 3$.

Fig. 9. Anal end of the "Palolo" or epitokal part of *E. viridis*, showing three of the ventral eye-spots and the empty preanal segments, and anal cirri. $\times\ 6$.

Fig. 10. The transition area between the "Palolo" and the atokal anterior part. Note the small size of the eye-spots on the posterior atokal segments. $\times\ 6$.

Fig. 11. The jaw apparatus of *E. viridis*, partly dissected. $\times\ 12$.

Fig. 12. Left half of the jaw apparatus dissected to show the component parts. $\times\ 15$.

Fig. 13. Parapodium of *E. viridis* from about the fortieth preanal segment. $\times\ 92$.

Fig. 14. End of one of the compound chætae of same. $\times\ 300$.

Fig. 15. Parapodium of *E. dubia*. This figure is inverted. $\times\ 200$.

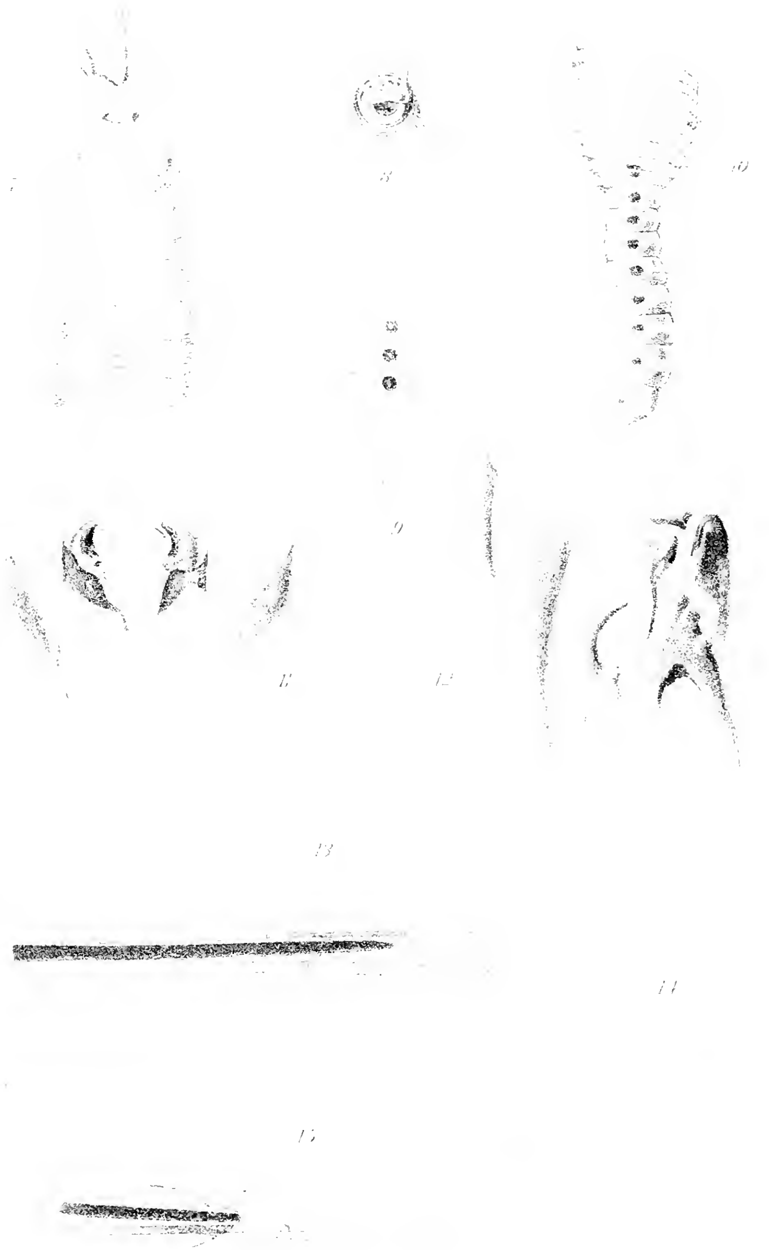
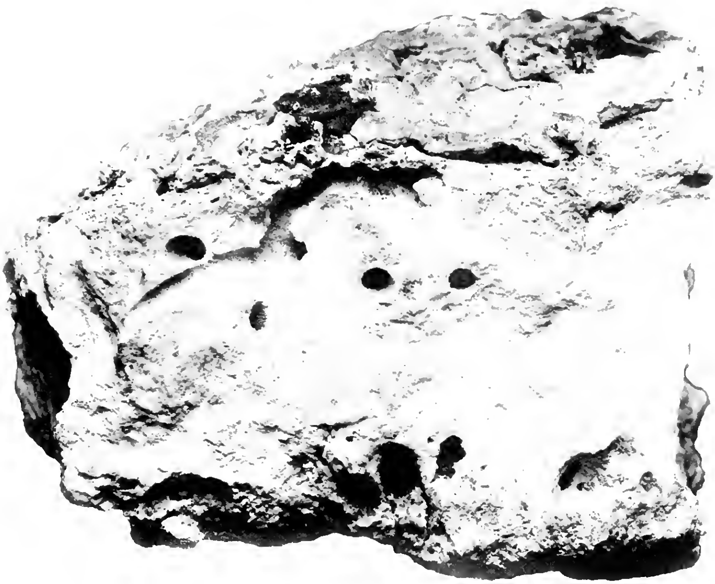
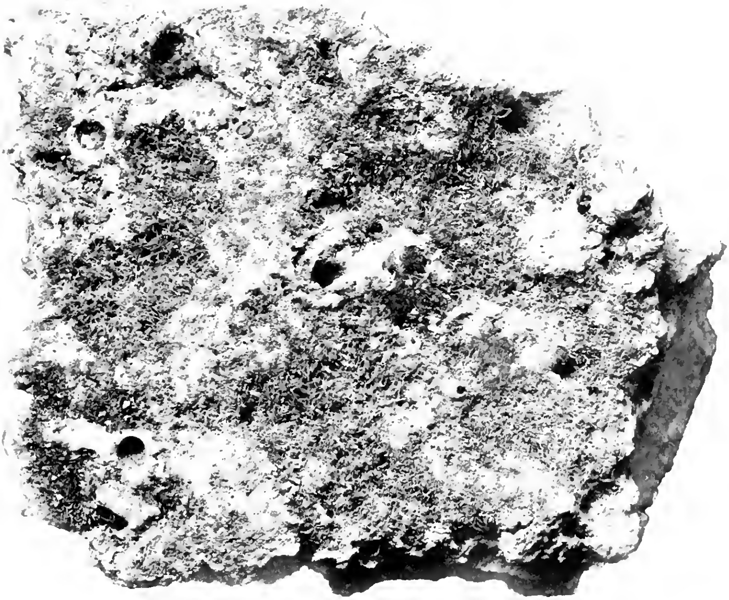


PLATE 3.

A piece of the reef-rock at Fagaiofu, showing the galleries and crevices occupied by the Palolo. The upper figure shows the fractured surface, the lower one a surface view of the reef-flat. From photographs. Natural size.





2

Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. LI. No. 2.

THE STARFISHES OF THE GENUS HELIASTER.

By Hubert Lyman Clark.

With Eight Plates.

CAMBRIDGE, MASS., U. S. A.:

PRINTED FOR THE MUSEUM.

June, 1907.

No 2. — *The Starfishes of the Genus Heliaster.* By Hubert Lyman Clark.

The starfishes placed by Gray (**1840**) in the group to which he gave the name Heliaster are of more than usual interest because of their limited geographical distribution their exclusively littoral habitat, and the large number of rays which they have. Moreover they appear to be remarkably plastic and there has long been reason to believe that the group contains several well-marked forms, limited to very circumscribed geographical areas. As the collection of the Museum of Comparative Zoölogy contains a large number of specimens from a dozen or more different localities, it seemed worth while to make a careful study of the group, especially with reference to three questions which have been raised concerning it. (1). How many valid species of Heliaster are there, what is their relation to each other, and what is the geographical distribution of each? (2). With how many rays does Heliaster begin its post-larval life, where and how do the new rays arise, in what order, and with how much variability? (3). What is the relation of Heliaster to Asterias and other starfishes, and by what systematic arrangement can that relationship best be shown? In finding the answers to these questions, we discover some important evidence on the subject of isolation as a factor in the formation of new species.

In addition to the material in the Museum collection, I am indebted to Dr. W. K. Fisher, of Leland Stanford Junior University, for the loan of material from the Galapagos Islands, belonging to the Museum of that University, and to Dr. Richard Rathbun, of the United States National Museum, for much valuable material from the collections under his care. To both of these gentlemen I herewith extend my sincerest thanks. In all I have had, from at least 15 distinct localities, 346 specimens of Heliaster, ranging from 20 to 300 mm. in diameter.

Historical.

The following annotated bibliography gives a complete resumé of our knowledge of Heliaster and its several species, from the first published reference in 1767 down to July 1, 1906: —

1767. **Davila, P. F.**

Catalogue systématique et raissoné des Curiosités de la Nature et de l'Art, qui composent le Cabinet de M. Davila, etc. 3 vols. **1**. Paris.

On p. 462–463 reference is made to three starfishes called "Tournesols," with 13, 37, and 38 rays, and brief descriptions are given of them; it is obvious that the two latter are Heliasters and it is fair to assume that they are *H. helianthus* (Lamarck) as that species was known in Paris, and was figured not many years later.

1791. **Bruguière, J. S.**

Tableau Encyclopédique et Méthodique, etc. Paris.

The two figures on plates 108 and 109 are fair abactinal and actinal views of a *Heliaster helianthus* (Lam.) with 29 rays.

1816. **Lamarck, J. B. P. A. de Monnet de**

Histoire Naturelle des Animaux sans Vertebres, etc. 7 vols. **2**. Paris.

On p. 558 Astérie hélianthe, *Asterias helianthus*, is given as the twentieth species of Asterias; it is said to have 30–36 rays (though reference is made to the figure of Bruguière, which has only 29) and to reach a diameter of 14–16 cm.; no locality is given.

1817. **Cuvier, G. L. C. F. D.**

Le Règne Animal, etc. 4 vols. **4**. Paris.

On p. 11, *Asterias helianthus* Lam. is listed but no information is given.

The numerous other editions and translations of Lamarck's and Cuvier's great works afford us no further information and there are no changes save that in the "Deuxieme Edition" (1840) of Lamarck the starfish is called "Astérie héliante," which is probably a misprint, and reference is made to the names *Solasterias* de Blainville and *Stellonia* Nardo, though neither is adopted; and in the German translation of Cuvier by Voigt (Das Thierreich, 1843) the species *helianthus* is listed under *Asteracanthion*, following Müller and Troschel.

1824. **Bory de Saint-Vincent.**

Tableau Encyclopédique et Méthodique, etc. Paris.

On p. 140 is the text to accompany the plates of Bruguière (1791), as follows:

Plate 108. Astérie, Asterias. 1–2. Asterias Helianthus, Lam., **2**, 558. (dessus).

Plate 109. Astérie, Asterias. 1–2. Asterias Helianthus, Lam., *loc cit.* (dessous).

1824. **Lamouroux, Bory de St. Vincent et Eud. Deslongchamps.**

Encyclopédie Méthodique. 10 vols. **2**. Paris.

On p. 119 is a direct quotation from Lamarck (1816) with the added note, "L'on ne connoît point son habitation."

1825. **Say, Thomas.**
On the species of the Linnean Genus *Asterias*, inhabiting the coast of the United States. Journ. Acad. Nat. Sci., **5**, p. 141–145. Philadelphia.

In a footnote on p. 145 is given the first published information in regard to the home of Heliaster.

" *A. Helianthus* Lam. As the native coast of this splendid species was unknown to Lamarck, I may . . . state that a fine specimen . . . was found near Guasco, . . . Chili."

1830. **Blainville, H. M. D. de.**
Zoöphytes: in Dictionnaire des Sciences Naturelles, etc. 60 vols. **60.** Strasburg et Paris.

On p. 222–223 *Solastéries* is proposed as a section of *Asterias*, admittedly artificial, for species with more than six rays, and *A. Helianthus* Lam. is named as one of them.

1834. **Blainville, H. M. D. de.**
Manuel d' Actinologie, etc. Paris.

On p. 241–242 is a repetition of the preceding suggestion, and a very poor figure of half the abactinal surface of *Helianthus* is given, plate 23, fig. 5.

1834. **Meyen, F. J. F.**
Reise um die Erde, etc. Theil **1.** Berlin.

On p. 222 *Asterias Helianthus* Lam. is said to be "besonders haüfig" on the coast at Valparaiso, and is considered the "ausgezeichnetesten" species of the genus.

1835. **Agassiz, L.**
Prodrome d'une Monographie des Radiaires ou Echinodermes. Mem. Soc. Sci. Nat., **1**, p. 168–199. Neuchâtel.

On p. 192, there is listed
" — *St. Helianthus* Ag. (Asterias Helianthus Lam.) —",
the *St.* being an abbreviation for *Stellonia* Nardo.

1840. **Müller, J. und Troschel, F. H.**
Ueber die Gattungen der Asterien, Arch. f. Naturg., Jahrgang 6, **1**, p. 318–326. Berlin.

On p. 321 *A. Helianthus* Lam. is listed as one of eight species of Asteracanthion, and on p. 324 the madreporite of the same starfish is said to be compound, a group of single plates.

1840. **Gray, John Edward.**

A Synopsis of the Genera and Species of the Class Hypostoma (Asterias, *Linnaeus*). Ann. Mag. Nat. Hist., **6**, p. 175–184. London.

On p. 179 is "Section e" of *Asterias, Heliaster*, defined thus: *Body discoidal, divided at the edge into numerous, short, tapering rays; the series of spines near the ambulacral series rather crowded, large and elongated.*

Asterias helianthus Lam. is given first, obviously as the type species, and is described as having 33 or 34 "arms," which are "about a quarter of the length of the width of the body." It is recorded from Guasco and Valparaiso, Chili. Then follow *Asterias Cumingii* with "arms 30 or 31, very short, not one-tenth as long as the diameter of the body," from "Hood's Island, on rocks at spring tide, *H. Cuming Esq.*," and *Asterias multiradiata* with "arms 22 or 24, cylindrical, elongated, tapering at the ends, one-third longer than the diameter of the body," from "Hood's Island, *H. Cuming Esq.*"

1840. **Gervais, P.**
Astérie, Asterias (*Actinoz*): in Dictionnaire Sciences Naturelles. Supplément. Paris.

On p. 469 *A. helianthus* Lamarck is assigned to *Stellonia* Nardo; reference is made to Gray's proposed section e (HELIASTER) of the genus *Asterias*, but curiously enough no mention is made of his proposed new species.

1842. **Müller, Johannes und Troschel, Franz Hermann.**
System der Asteriden. Braunschweig.

On p. 18–19 is given *Asteracanthion helianthus* nob., including *Asterias helianthus* Lamarck, *Asterias Cumingii* Gray and *Asterias multiradiata* Gray. The two latter are dismissed with the brief statement that they "do not appear to us to be different." The compound nature of the madreporite is referred to, the size is said to be "up to one foot" and the native coast is given as "Chili, Pacific Ocean."

1843. **Müller, Johannes.**
Über den Bau des Pentacrinus caput Medusae. Berlin.

Abschnitt 8. Ueber die Unterschiede des Baues der Crinoideen und Asteriden, p. 61–68.

On p. 64 *Asteracanthion Helianthus* Lam. is listed and on p. 67, the compound nature of the madreporite is mentioned.

1843. **Müller, J. und Troschel, F. H.**
Neue Beiträge zur Kenntniss der Asteriden. Arch. f. Naturg. Jahrgang 9, **1**, p. 113–131. Berlin.

On p. 128 *Asteracanthion helianthus* is listed among starfishes from the west coast of South America.

1854. **Gay, Claudio.**
Historia fisica y politica de Chili, etc. 26 vols. Zoölogia. **8.** Paris. Santiago.

On p. 425 is a good account of the "Estrella del Mar," *Asteracanthion helianthus*. It is said to have 28–39 rays and to occur at Valparaiso and elsewhere on the coast of Chili.

1856. Hoeven, J. Van der, translated by William Clark.
Handbook of Zoölogy. 2 vols. **1.** Cambridge (England).

On p. 148–149 *Asterias helianthus* with "rays up to 30 and more" is said to be "one of the most remarkable and most beautiful species."

1857. Carpenter, Philip P.
Report on the present state of our knowledge with regard to the Mollusca of the west coast of North America. Rept. British Ass. for 1856, p. 159–368. London.

On p. 360 it is stated that *Stylifer astericola* is known from the Galapagos parasitic in *Asterias solaris.* The starfish referred to is unquestionably a Heliaster and probably *H. cuningii* Gray, as many specimens of that species from the Galapagos are parasitized by Stylifer; the name *solaris* would be more naturally applied to this species than to *multiradiatus,* the other Galapagos Heliaster, because of its more numerous rays.

1857. Philippi, A.
Vier Neue Echinodermen des Chilenischen Meeres. Arch f. Naturg., Jahrgang 23, **1**, p. 130-134. Berlin.

On p. 134 *Asteracanthion helianthus* is listed among the starfishes of Chili.

1857. Stimpson, Wm.
On the Crustacea and Echinodermata of the Pacific Shores of North America. Boston Journ. Nat. Hist., **6**, p. 444–532, plates 18–23. Boston.

On p. 529 *Asterias helianthus* Lam. is given as occurring at "Mazatlan (Moores)." Probably *H. microbrachius* is the species intended.

1860. Lütken, Chr.
Bidrag til Kundskab om de ved Kysterne of Mellemog Syd-America levende Arter of Söstjerner. Videns. Meddel. for 1859, p. 25–96. Kjöbenhavn.

There are several references in this paper (p. 27, 31, 32, 35) to the occurrence of Heliasters on the western coast of America, but the writer considers the species in each case to be *helianthus.* In a footnote on p. 32, he indicates his doubt as to the location of Hood's Island, his disbelief in Gray's proposed species, and his final opinion that even if valid they do not enter into the West American fauna.

1860. Bronn, H. G.
Die Klassen und Ordnungen des Thier-reichs, etc. Die Klassen und Ordnungen der Strahlenthiere (Actinozoa). Leipzig und Heidelberg.

On p. 253 reference is made to the compound madreporite of *Asteracanthion helianthus.*

1860. Xantus, John.
Descriptions of Three New Species of Starfishes from Cape St. Lucas. Proc. Acad. Nat. Sci., 1860, p. 568. Philadelphia.

On p. 568 are the original descriptions of *Heliaster microbrachia* and *H. kubiniji*. The former is said to have 35 rays, the free portion equalling one-eighth of the diameter and the dorsal spines very small and numerous. The latter has 22–24 rays, the free portion rather less than one-third of the diameter, and the dorsal spines capitate; the name is said to be in honor of "my countryman, M. Kubiniji, the accomplished director of the Hungarian National Museum at Pesth." Each species is said to be 7 inches in diameter. The specimen of *microbrachia* was from Cape St. Lucas, while that of *kubiniji* was from "Cerro Blanco, Cape St. Lucas."

1862. **Dujardin, F. et Hupé, H.**

Histoire Naturelle des Zoophytes Échinodermes, etc. Paris.

On p. 329, 343 and 344 *Heliaster* Gray is recognized as a genus, and with *Asteracanthion* forms the first of the three tribes of Asterides. The species *Cumingii* Gray and *multiradiatus* Gray are however considered doubtful, and although the characters given by Gray are mentioned, the species are included in the synonymy of the single accepted species, *Heliaster Helianthus* Lam. (Sp.). The color of this species is said to be "variée de blanc et de noir, comme tigrinée"; the size, 20–30 cm.; the distribution, "Coast of Chili" (thus ignoring Gray's records from the Galapagos). The gastropod *Stylifer* is recorded as a parasite. No mention is made of Xantus's paper (1860) or of his proposed species.

1866. **Martens, E. von.**

Ueber Ostasiatische Echinodermen. Arch f. Naturg., Jahrgang 32, **1**, p. 57–88. Berlin.

On p. 60 *Heliaster* is used as a subgenus of *Echinaster* to include *solaris* Schmidel, and "Hupé und Dujardin" are quoted for authority. In this extraordinary slip of the pen are three distinct errors. (1) Hupé and Dujardin never published anything with the former as senior author. (2) Dujardin and Hupé (1862) use Heliaster as a separate genus and neither they nor any other author ever used it as a subgenus of, or allied to Echinaster. (3) Schmidel never gave the name *solaris* to any species of starfish, though in 1781 he described one, to which Schreber, twelve years later, gave that name! The starfish to which von Martens refers is obviously *Acanthaster echinites* (Ellis and Solander). — On p. 68 von Martens speaks of the peculiar madreporite of *Asterias helianthus.*

1866. **Gray, John Edward**

Synopsis of the Species of Starfish in the British Museum. London.

On p. 2 is what is practically a reprint of that part of p. 179, Gray 1840, which deals with Heliaster, except that *Heliaster* is now section f, instead of section e, of the genus *Asterias.*

1867 a. **Verrill, A. E.**

Notes on the Echinoderms of Panama and West Coast of America, with descriptions of new Genera and Species. Trans. Conn. Acad., **1**, p. 251–322. New Haven.

On p. 289-293 are good descriptions of *Heliaster helianthus*, *microbrachia*, *Cumingii* and *Kubiniji*, with special attention given the pedicellariae. The description of *Kubiniji*, which is considered distinct from *multiradiata* Gray, is based on a specimen "obtained at the Sandwich Islands. It probably came from Acapulco or Mazatlan." This specimen is of interest chiefly because, through a mistake of Perrier's, it is the source of all Hawaiian records.

1867 [b]. **Verrill, A. E.**
On the Geographical Distribution of the Echinoderms of the West Coast of America. Trans. Conn. Acad., **1**, p. 323–351. New Haven.

The geographical distribution of the genus *Heliaster* and of *H. Cumingii*, *helianthus*, *Kubiniji*, *microbrachia*, and *multiradiata*, is referred to on p. 328, 329, 331, 333-335, 344, and 348.

1868. **Claus, Carl**
Grundzüge der Zoologie, etc. Marburg und Leipzig.

On p. 107 *Asteracanthion helianthus* is referred to as having "30 und mehr" rays.

1869. **Perrier, Edmond.**
Recherches sur les Pédicellaires et les Ambulacres des Asteries et des Oursins. Ann. Sci. Nat., (5) **12**, p. 197–304, plates 17–18. Paris.

On p. 202–203 Heliaster is recognized as a good genus, but on p. 231 the writer decides it is not valid. A description of the pedicellariae of Asteracanthion and Heliaster occupies p. 202–219 and on plate 7 is a figure (16) of a forcipiform pedicellaria of *Asteracanthion helianthus*. On p. 203 it is stated: "Dans toutes les espèces appartenant aux genres *Asteracanthion* et *Heliaster* on trouve deux sortes de Pédicellaires, nous designerons . . . l'une . . . *Pédicellaires droits*, l'autre . . . *Pédicellaires croisés*." But on p. 231 under *Heliaster helianthus*, the writer says, "Nous ne connaissons pas encore les pédicellaires droits"!

1869. **Verrill, A. E.**
On New and Imperfectly Known Echinoderms and Corals. Proc. Boston Soc. Nat. Hist., **12**, p. 381–396. Boston.

On p. 387 are some notes on a large specimen of *Heliaster Kubiniji* from La Paz having 23 rays.

1871 [a]. **Verrill, A. E.**
Additional Observations on Echinoderms, chiefly from the Pacific Coast of America. Trans. Conn. Acad., **1**, p. 568–593. New Haven.

On p. 578 are some further notes on *Heliaster Kubiniji* Xantus.

1871 b. Verrill, A. E.

The Echinoderm Fauna of the Gulf of California and Cape St. Lucas. Trans. Conn. Acad., **1**, p. 593–596. New Haven.

This brief paper contains several references to the geographical distribution of Heliasters on the coast of Mexico.

1871. Cunningham, Robert O.

Notes on the Natural History of the Strait of Magellan and West Coast of Patagonia, etc. Edinburgh.

On p. 404 a 38-rayed specimen of *Heliaster helianthus* is referred to as a "huge" starfish taken at Pelican Rock, near Coquimbo, Chili. Unfortunately no measurements are given.

1871. Lütken, Chr.

Fortsatte kritiske og beskrivende Bidrag til Kundskab om Söstjernerne (Asteriderne). Viddens. Meddel. for 1871, p. 227–304, plates 4–5. Kjöbenhavn.

On p. 289 is an unimportant reference to "*Asterias microbrachia* Xantus," and on p. 304 the occurrence of that species and "*Heliaster Kubinjii*" at Altata, Mexico, is noted.

1872. Lütken, Chr.

Om Selvdeling hos Echinodermer og andre Straaldyr. Overs. K. Danske Vid. Sels. Forh. for 1872, p. 108–157. Kjöbenhavn.

On p. 121 is a trivial reference to Heliaster and in a footnote (2) on p. 125 et seq. is an interesting discussion of the correlation between size and number of rays in "*Asterias helianthus*," "*microbrachia*," "*Kubinjyi*," and "*Cummingii*."

1875. Perrier, Edmond.

Révision de la Collection de Stellérides du Muséum d'Histoire Naturelle de Paris. Arch. Zool. Exp., **4**, p. 265–450. Paris.

The genus *Heliaster* Gray is approved and placed in the Asteriadae (p. 285–286) and a diagnosis is given (p. 299). Later (p. 351) it is given as the fifth genus of the Asteriadae, with four species:

H. microbrachia Xantus. Acapulco.
H. kubiniji Xantus. Acapulco.
H. helianthus (Lam.). Chili.
H. canopus, sp. nov. (Mss. Valenciennes). Juan Fernandez.

The writer considers *microbrachia* the best characterized species, and describes *canopus*, which he says is 70 mm. in diameter and has only 24 rays, and may prove to be the young of *helianthus*. Perrier does not mention *multiradiatus*, but states that he could not find Gray's *cumingii* at the British Museum.

1878. Perrier, Edmond.

Étude sur la Répartition Géographique des Astérides. Nouv. Arch. Mus. d'Hist. Nat., (2) **1**, p. 1–108. Paris.

The geographical distribution of Heliaster is fully discussed in this paper on p. 8, 11, 75, 76, 98–100. By a curious slip of the pen on p. 43, Heliaster is said to be peculiar to "le côte orientale" of America, and the same slip is repeated with reference to Pycnopodia.

1878. Viguier, M.

Anatomie Comparée du Squelette des Stellérides. Arch. Zool. Exp., **7**, p. 33–250, plates 5–16. Paris.

This very important paper deals fully (p. 61, 63, 93, 99, 111–116) with the skeletal anatomy of Heliaster, and discusses its relationship with other starfishes. On plate 6 are given some structural details (figs. 4–12). The conclusion is reached that the peculiarities of Heliaster are sufficient to warrant its elevation to family rank, as the HELIASTERIDAE.

1883. Perrier, Edmond.

Mémoire sur les Étoiles de Mer, recueillies dans la Mer des Antilles et le Golfe du Mexique, etc. Also entitled: Stellérides des Dragages du "Blake." Nouv. Arch. Mus. d'His. Nat., (2) **6**, p. 127–276, plates 1–10. Paris.

The family Heliasteridae is recognized in this work, although the references to it (p. 139, 143, 153, 154) and to the type genus are unimportant.

1885. Lockington, W. N.

Echinodermata; under Lower Invertebrates, Standard Natural History. 6 vols. **1**, Asteroidea, p. 152–161. Boston.

On p. 160 the genus Heliaster (apparently under the "Asteridae") is referred to as having two species, *kubiniji* and *microbrachia*, on the west coast of North America from Panama to Cape St. Lucas.

1886. Ludwig, Hubert.

Dr. Johannes Leunis Synopsis der Thierkunde, etc. 2 vols. **2**. Hannover.

On p. 934 *Heliaster* Gray is given as a genus of Asteriadae, with "mehrere Arten," but *helianthus* (Lam.) Gray is the only one mentioned.

1887. Rathbun, Richard.

Descriptions of the species of *Heliaster* (a genus of starfishes) represented in the U. S. National Museum. Proc. U. S. Nat. Mus., **10**, p. 440–449, plates 23–26. Washington.

In this, the most important paper published dealing with the taxonomy of Heliaster, four species are clearly distinguished, fully described, and admirably figured. The writer considers *H. kubiniji* Xantus (which is spelt

Kubingii throughout the paper) as identical with *multiradiata* Gray, while *H. canopus* Perrier is not mentioned. By a curious slip of the pen, Verrill's paper of 1869 is quoted as Amer. Jour. Sci. instead of Proc. Boston Soc. Nat. Hist.

1889. Ives, J. E.

Catalogue of the Asteroidea and Ophiuroidea in the Collection of the Academy of Natural Sciences of Philadelphia. Proc. Acad. Nat. Sci., 1889, p. 169–179. Philadelphia.

On p. 170 " *H. helianthus* Lam., *microbrachia* Xantus, *multiradiata* Gray (= *Kubiiniji* Xantus) " are listed under the Asteriidae.

1889. Sladen, W. Percy.

Report on the Asteroidea collected by H. M. S. " Challenger " during the years 1873–1876. Rept. Sci. Results Voy. H. M. S. " Challenger." 32 vols. **30**, xlii, 893 pp., 118 plates. Edinburgh and London.

This magnificent monograph contains numerous references (p. xiii, xx, xxi, xxxix, xlii, 555, 556, 671, 686, 690, 701, 812, 813) to the anatomy, systematic position, and geographical distribution of Heliaster and the Heliasteridae. The author is very sceptical as to whether the genus contains more than a single species, and speaks several times of the " so-called " species.

1891. Perrier, Edmond.

Echinodermes I. Stellerides. Mission Scientifique du Cap Horn, **6**. Zoologie, p. K 1–K 198, plates 1–13. Paris.

On p. K 60, K 61, and K 67 are references to the number of rays, and formation of new rays, in Heliaster.

1892. Meissner, Maximillian.

Asteriden gesammelt von Herrn Stabsartz Dr. Sander auf der Reise S. M. S. "Prinz Adalbert." Arch. f. Naturg. Jahrgang 58, **1**, p. 183–190, plate 12. Berlin.

On p. 184 nine examples of *H. helianthus* Lam., with from 30 to 38 rays each, are recorded from Callao, Peru.

1893. Perrier, Edmond.

Traité de Zoologie. Paris.

On p. 781 and 847 are unimportant references to Heliaster.

1894. Lang, Arnold.

Lehrbuch der Vergleichenden Anatomie der Wirbellosen Thiere. — Echinodermata. p. 871–1154. Jena.

On p. 884 is this: 7. Familie. Heliasteridae. Mit zahlreichen, kurzen-armen. Heliaster.

1894. Perrier, Edmond.

Echinodermes: in Exp. Sci. du Travailleur et du Talisman, etc. 431 pp., 26 plates. Paris.

On p. 4 and 27 are unimportant references to the Heliasteridae; on p. 22 Heliaster is said to have "quarante bras et plus," but it is fair to assume that "jusqu'à" is to be understood; on p. 43 Heliasteridae is again referred to and listed as the third family of Forcipulata.

1895. Sluiter, C. Ph.

Die Asteriden-Sammlung des Museums zu Amsterdam. Bijdr. Dierk., **17**, p. 49–64. Amsterdam.

On p. 64 the family Heliasteridae is recognized and *H. helianthus* is listed from Chili.

1895. Leipoldt, Fritz.

Asteroidea der "Vettor-Pisani" Expedition (1882–1885). Zeit. f. w. Zool., **59**, p. 545–654, plates 31–32. Leipzig.

On p. 546–552 are very useful accounts of the distribution and the pedicellariae of *H. helianthus*, *cumingii*, *multiradiatus*, and *microbrachius*. Good figures of the jaws of the pedicellariae are given on plate 31, figs. 1 and 2. The peculiar coloration of specimens of *multiradiatus* from the Galapagos Islands is well described. Perrier's record of that species from the "Iles Sandwich" is very properly regarded with doubt.

1896. Plate, Ludwig H.

Zur Kenntnis der Insel Juan Fernandez. Verh. Gesellsch. Erdk. Berlin, nos. 4 und 5, p. 221–229. Berlin.

On p. 224 *H. helianthus* is reported as one of the five starfishes occurring at Juan Fernandez; some further notes are given concerning its occurrence on the South American coast.

1896. Meissner, Maximillian.

Die von Herrn Dr. L. Plate aus Chili und Feuerland heimgebrachten See-Sterne. Arch. f. Naturg. Jahrgang 62, **1**, p. 91–108. Berlin.

On p. 102 *H. helianthus* is reported from Chili as the common starfish of the coast rocks. Two young ones with 12 and 22 rays each are recorded, but, strangely enough, nothing is said as to the size of either. The writer remarks on its being unfortunate that Dr. Plate failed to bring home any specimens of Heliaster from Juan Fernandez, since he reports (1896) *H. helianthus* as being common there, while the specimens upon which Perrier based his species *canopus* (1875) came from that island, and Dr. Plate, by bringing home a series of specimens, might have settled the question as to the authenticity of that species.

1897. **Harrington, N. R. and Griffin, B. B.**
Notes upon the Distribution and Habits of some Puget Sound Invertebrates. Trans. N. Y. Acad., **16**, p. 152–165. New York.

On p. 156 is the following mistake: "The commonest sea-star, a gigantic species of *Heliaster*, finds shelter beneath the wharves, etc." Of course, *Pycnopodia helianthoides* is the species referred to.

1899. **Ludwig, H. and Hamann, O.**
Echinodermen: Asteroidea: in Dr. H. G. Bronn's Klassen und Ordnungen des Thier-reichs, etc. **2.** Leipzig.

On p. 566–568 the madreporite of Heliaster is discussed and on p. 713 the family Heliasteridae is accepted with the single genus, Heliaster, and five species, *canopus* Perrier being added to the four described by Rathbun (**1887**).

1900. **Gregory, J. W.**
The Stelleroidea: in Bather's Echinoderma, chap. 13, p. 237–281: in E. Ray Lankester's A Treatise on Zoölogy, Part 3. London.

On p. 258 the family Heliasteridae is accepted with two subfamilies; HELIANTHASTERINAE with the single Devonian genus, *Helianthaster* and HELIASTERINAE with the single recent genus *Heliaster*.

1900. **Ritter, W. E. and Crocker, Gulielma R.**
Multiplication of Rays and Bilateral Symmetry in the 20-rayed Starfish, *Pycnopodia helianthoides* (Stimpson) Proc. Wash. Acad. Sci., **2**, p. 247–274, plates 13–14. Washington.

In discussing the method of ray formation in multiradiate starfishes, there are some references (p. 249 and 263) to Heliaster, based however on assumption and not on investigation.

1902. **Goette, Alexander.**
Lehrbuch der Zoologie. Leipzig.

On p. 319 *Heliaster helianthus*, "mit zahlreichen Armen," is given as an example of the Cryptozonia.

1902. **Kingsley, J. S.**
Hertwig's Manual of Zoölogy. New York.

On p. 337 *Heliaster* is given as an example of a starfish with numerous well developed rays and "ambulacra in four rows."

1902. **Clark, Hubert Lyman.**
Echinodermata: in Papers from the Hopkins-Stanford Galapagos Expedition, 1898–99. Proc. Wash. Acad. Sci., **4**, 521–531. Washington.

On p. 523–524 are some notes on *H. cumingii* and *multiradiatus*.

1903. **Delage, Yves et Herouard, Ed.**
Traité de Zoologie Concrète. 9 vols. **3.** Les Echinodermes. Paris.

On p. 103 is this:
7 Fam.: Heliasterinae [*Heliasteridae* (Vignier); p. p. *Forcipulata* (Perrier)] — Heliaster (Gray). Bras 25 au moins. Helianthaster (Römer) (Dev.).

1906. **Fisher, Walter K.**
The Starfishes of the Hawaiian Islands. Bull. U. S. Fish Commission for 1903, part 3, p. 987–1130, plates 1–49. Washington.

On p. 989, 994, and 998 are brief references to *H. multiradiatus*, and on p. 1002 the family Heliasteridae is included in the Key. On p. 1104 *H. multiradiatus* is admitted to the Hawaiian fauna on the strength of Sladen's statement, but serious doubt is expressed as to the validity of the record.

As a result of the examination of this literature, our present knowledge of Heliaster may be briefly summarized as follows: Six species have been described, of which one (*kubiniji* Xantus) is commonly considered identical with another (*multiradiatus* Gray), while a third (*canopus* Perrier) is regarded as possibly the young of a fourth (*helianthus* Lamarck), and by some writers the remaining two are not considered as really distinct. The geographical limits of the genus are fairly well known, but there is still some question about the limits of the several species. The external morphology, including the pedicellariae, is very well known and the skeletal characters especially of the oral surface have been well worked out. But the internal anatomy is practically unknown, and almost nothing is recorded of the habits; absolutely nothing of the development. The amount of variability within a single species is little understood and almost nothing is known of the formation of the new rays in passing from the young stages with relatively few, to the older condition with very numerous, rays. Finally the relationship to other genera is most imperfectly understood, although there is general agreement in placing the genus apart in a family by itself.

Systematic.

We naturally turn first of all to an investigation of the number and validity of the species which Heliaster contains, and the material at hand enables us to settle all of the disputed questions in regard to this matter. In his admirable report on the Heliasters of the United States

National Museum, Rathbun (**1887**) has shown beyond question the existence of at least four well-marked species, and the present investigation confirms his conclusion. But Rathbun had no material from Juan Fernandez, and consequently does not refer to *canopus* Perrier, while he had only a few specimens from the Galapagos, and these he naturally assigns to the species named by Gray, which came from Hood's Island. The material now available, includes a fine series of adults and young from Juan Fernandez, which confirms Perrier's opinion that the species occurring at the island is quite different from *helianthus* and is entitled to recognition as a distinct species, *canopus*. The number of specimens from the Galapagos makes it possible to show that the Heliasters of that group of islands present certain characters in which they are obviously and apparently constantly different from their nearest allies on the American coast. Of course there is room for difference of opinion as to whether these characters are sufficiently tangible and constant to warrant calling the island forms separate species, but since the characters are associated with sharply distinct geographical areas (for Heliaster is littoral in the extreme) and since the island forms were long ago named by Gray, and one of the mainland near allies by Xantus, it seems better to give the other mainland ally a name, and thus recognize seven species of Heliaster. In no other way can the apparent plasticity of the genus and the results of isolation be so well brought out.

Heliaster Gray.

Asterias; section e, Heliaster Gray, 1840. Ann. Mag. Nat. Hist., **6**, p. 179.
Heliaster (used without comment as a generic name) Xantus, 1860. Proc. Acad. Nat. Sci. Phil., p. 568.
Heliaster Dujardin et Hupé, 1862. Hist. Nat. Zooph. Echin., p. 343.
Asterias; section f, Heliaster Gray, 1866. Syn. Starf. Brit. Mus., p. 2.
Heliaster Perrier, 1875. Arch. Zoöl. Exp., 4, p. 299.

Since Perrier's diagnosis the genus Heliaster Gray has been universally recognized.

Gray's diagnosis was as follows: —

Body discoidal, divided at the edge into numerous short tapering rays; the series of spines near the ambulacral series rather crowded, large, and elongated.

To this characterization, Perrier added nothing, but Viguier (**1878**) suggested as additional features the funnel-shaped depression in which the mouth is placed, the fragmentation of the madreporite, the double interbrachial walls, and the fused condition of that interradial plate which he calls the "odontophore." Unfortunately the first and last of these characters are of doubtful value, and the

second is not true of all Heliasters. The third, although quite characteristic, is not confined to this genus. Accordingly, the following diagnosis of the genus, which represents our present knowledge, does not differ markedly from that of Gray: —

Disc large, not set off externally from the fused bases of the rays, little elevated, with reticulated abactinal skeleton, and more or less numerous spines, pedicellariae, and papulae. Rays numerous, more than 20 in normal adults, more or less united at base, so that only a relatively small part (15–70%) is free.[1] Adambulacral armature variable, usually single, sometimes double, especially near tip of ray; spines of alternate plates often of two sharply contrasted sizes, especially near base of ray. Pedicels arranged in two more or less zigzag rows, so that near middle of ray they are, as a rule, distinctly quadriserial. Forcipate and forficate pedicellariae both present, the latter often of two quite distinct sizes. Interbrachial septa double and well developed, expanding at inner (proximal) end and uniting laterally more or less extensively, to form a discobrachial wall, so that the cavity of the disc is almost completely separated from the cavities of the rays. (See plate 6, fig. 1).

This well-marked genus is easily distinguished by the number of rays alone, from all other starfishes except *Pycnopodia* and *Labidiaster*. From the former it is readily separated by the well-developed abactinal skeleton, the large disc and the fused rays. From Labidiaster it differs in the fused rays and quadriserial pedicels. The double interbrachial septa with the remarkable discobrachial wall are internal features, distinguishing Heliaster from either genus. — The distribution of Heliaster is remarkably restricted as it occurs only in very shallow water along the tropical and subtropical coasts of the eastern Pacific Ocean. I can find no record of a specimen being taken with a dredge or trawl, so that they are apparently littoral starfishes in the strictest sense of that term. They occur upon and among rocks in the neighborhood of low-water mark. The most northern point of their range, as shown by the specimens before me is San Luis Gonzales Bay, Gulf of California, in latitude 29° 15′ N., while the southern extreme on the mainland appears to be in the vicinity of Valparaiso, 33° 2′ S. lat. There are no published records of the occurrence of Heliaster, either north or south of these limits, and it is not recorded from any of the outlying islands, save Juan Fernandez, 33° 38′ S. lat., and the Galapagos, on the equator. — Nothing has been recorded of the habits of Heliaster, but preserved specimens show that the food consists very largely of small mussels, limpets, and acorn-shells (barna-

[1] In estimating the percentage of ray that is free, the length of the free portion is divided by R. (*i. e.*, the distance from centre of abactinal surface of disc to tip of ray) as it is not feasible to measure the actual length of ray. Consequently the free part is really a larger proportion of the ray itself than the percentages herein given would seem to indicate. It should also be noted that the rays are fused to a much greater extent relatively in adult than in young specimens; very young individuals often have twice as much free ray as adults of the same species.

cles). In two cases a half of a small fish was found in the stomach, but it is probable that the fish were found dead on the rocks among the mollusks and barnacles on which the Heliaster was feeding. — Parasitic gastropods (*Stylifer*) are common on specimens of Heliaster from the Galapagos Islands and occur not infrequently on specimens from the South American coast.

The following keys show the characters by which the seven species here recognized are to be distinguished. The first is wholly morphological and shows the species in what is probably their natural relationship. The second is quite artificial and takes into account the geographical distribution; it may be found useful in identifying specimens from known localities, where a large series of individuals is not available for comparison. In using these keys, it must be borne in mind that the number of rays is fewer in young individuals than in adults and that (as already mentioned) they may be free for a much greater proportion of their length. Consequently specimens under one hundred millimeters in diameter cannot always be certainly identified by means of these keys alone.

Key to the Species.

A. Rays free for 30 per cent of their length, or more.

B. Rays 30 or more, free about 35 (30–40) per cent of their length . . . . *helianthus*

BB. Rays 28 or fewer, free for 40–70 per cent of their length.

C. Spines on abactinal surface of disc numerous, little or not at all capitate, smaller than those which form conspicuous marginal series on abactinal surface of rays; between these marginal series is a median series with a lateral series on each side; latter generally inconspicuous and made up of very small spines; marginal series converge on disc, confining median series to ray . . . . *canopus*

CC. Spines on abactinal surface of disc comparatively few, many of them usually conspicuously capitate and larger than those of marginal series of rays; between latter are three or more not very clearly defined series of which the median is most conspicuous and continues inwardly onto the disc.

Rays free for more than half their length, 50–70 per cent; color, abactinally, pale yellowish mottled with blackish, the rays more or less distinctly banded; spines, pedicellariae, and madrepore plate, light yellowish . . . . *multiradiatus*

Rays free usually for less than half their length, 40–55 per cent; color, abactinally, deep purplish; spines, pedicellariae, and madrepore plate, more or less deep yellow; rays sometimes indistinctly banded . *kubiniji*

AA. Rays free for less than 30 per cent of their length, rarely less than 30 in number in adults.

B. Abactinal surface covered with numerous small, often subacute, rarely capitate, spines of nearly uniform length, not arranged in radiating series except on rays, where five such series are usually more or less evident . . . . . . *microbrachius*

BB. Abactinal surface with rather large, often capitate spines, arranged in more or less distinct radial series, especially on rays, where three such series are very evident.

Abactinal spines not very numerous, 15–20 per sq. cm. where thickest, more or less cylindrical, often subacute, rarely distinctly capitate; pedicellariae often wanting on actinal surface; rays often free for more than 20 per cent of their length . . . . *cumingii*

Abactinal spines more numerous, 25–50 per sq. cm. where thickest, low, usually capitate; pedicellariae frequent on actinal surface; rays seldom free for more than 20 per cent of their length . . . . *polybrachius*

Artificial Key to the Species.

A. Rays more than 30, rarely as few as 27 or 28.

B. Rays free for 30 per cent of their length or more; west coast of South America . . . . *helianthus*

BB. Rays free for less than 30 per cent of their length.

C. Abactinal surface with very numerous small spines, rarely capitate; five subequal series on rays; west coast of Mexico and Central America . . . . . *microbrachius*

CC. Abactinal surface with fewer, larger, capitate spines; three series on rays.

Abactinal spines not crowded, little or not at all capitate; Galapagos Islands . . . . *cumingii*

Abactinal spines numerous, often crowded, especially near margin of disc, usually distinctly capitate; west coast of tropical South America . . . . *polybrachius*

AA. Rays never more than 28.

B. Abactinal surface of disc with spines smaller than the marginal series on rays; diameter of adult 80–120 mm.; Juan Ferdandez . . . . *canopus*

BB. Abactinal surface of disc with large, often capitate spines; diameter of adult 110–180 mm.

Rays free for 40–55 per cent of their length; west coast of Mexico and Central America . . . . *kubiniji*

Rays free for 50–70 per cent of their length; Galapagos Islands . . . . *multiradiatus*

Heliaster helianthus (Lamarck).[1]

Plate 3, Fig. 1; Plate 7, Figs. 1-7.

Tournesol Davila, 1767.
Asterias helianthus Lamarck, 1816.
Stellonia helianthus Agassiz, 1835.
Asteracanthion Helianthus Müller and Troschel, 1842.
Heliaster helianthus Dujardin and Hupé, 1862.

Description. — Rays 30–40, averaging (51 individuals) 34.8; about 35 (29–43) per cent of ray, free. R=75–150 mm.; r=45–90 mm. Breadth of ray at base, 8–15 mm. R=7–9 br. Rays more or less flattened both actinally and abactinally, angular with nearly vertical sides, commonly tapering but often abruptly blunt-pointed, becoming more nearly terete near tip. Disc large, little or not at all elevated above base of rays; in a specimen with R=150 mm. the vertical diameter is only about 30 mm.[2] Abactinal surface covered with a stout, reticulated skeleton having rather small meshes. Skeletal plates with numerous spines of variable size, form, and arrangement. There are usually three well-marked series on each ray and these continue inward onto the disc far beyond the base of the ray; the median row is the most conspicuous and includes numerous clusters of more or less capitate spines; the lateral rows contain fewer spines, commonly arranged in a single series, which may be larger or smaller, and more or less capitate, than those in the median row. The lateral rows are nearly parallel with each other and remain separate, so that the median series is also present proximally. On the central part of the disc, the prominent and usually capitate spines do not show a serial arrangement but they are commonly grouped in more or less irregular, short lines, which form a sort of imperfect reticulation. In some specimens this network is quite distinct, the meshes being three or four millimeters in diameter and each side of a mesh consisting of a crowded single series of from three to seven spines. In other specimens no reticulation is evident, the spines being irregularly scattered, although here and there a few tend to form a crowded, linear series. Specimens sometimes occur in which no arrangement of the abactinal spines is evident even on the rays, but they appear to be scattered irregularly everywhere. Besides the conspicuous spines, smaller and more slender ones frequently occur abactinally, and pedicellariae, chiefly of the forcipate type, are more or less abundant, especially near the tips of the rays, while papulae occur everywhere. — Sides of rays with three or four longitudinal series of spines which are usually very

[1] No attempt is made to give complete synonymies of the seven species, as that would involve a virtual repetition of the bibliography already given. Only such names are listed as show some difference from the one originally given or the one herein accepted. It should be noted in passing that Gray never used Heliaster as a generic name and never published it in direct connection with any specific name; consequently it is not correct to write "*Heliaster helianthus* (Lam.) Gray" as has often been done; if two authors are to be referred to, the name should be written as Sladen gives it, "*Heliaster helianthus* (Lam.) Dujardin and Hupé."

[2] It is useless to attempt to distinguish externally the true limits of the disc, and the term is used in these descriptions to include the fused basal portion of the rays.

markedly compressed, among which are numerous pedicellariae and papulae. — Actinal surface of disc almost entirely occupied by ambulacra, adambulacral spines, pedicellariae, and papulae; interbrachial areas reduced to a minimum. — Adambulacral plates with typically a single, conspicuous, erect spine. In young specimens these may all be of equal size, but in adults, near the middle of the ray, larger and smaller spines alternate, so that every other plate has a small spine standing between the larger spines of the neighboring plates. The smaller spines are commonly almost or quite within the furrow. In some specimens the small spines are wholly wanting proximally so that only every other plate carries a spine. As a rule the spines are all of a nearly uniform size near the tip of the ray. On the distal half of the ray, some of the adambulacral plates often carry two spines, one behind the other. Beginning just proximal to the base of the ray and running outward to the tip, a series of large spines is found just outside the adambulacral series, and this is followed by one or two more, each series slightly shorter than its predecessor. These additional actinal spines differ greatly in number and size in different specimens, apparently increasing with the age of the animal. The adambulacral spines on the middle and proximal part of the ray are the largest spines of the actinal surface and may be as much as five millimeters long. Along the sides of the ambulacral furrows, among the adambulacral and other spines, are numerous pedicellariae, chiefly of the forficate type and of two quite distinct sizes (Plate **7**, figs. 2, 3); but the size and abundance of the pedicellariae vary greatly in different individuals. — At the centre of the actinal surface occurs the very large buccal membrane, thin, smooth, and conspicuous, with the mouth at the centre. The membrane in a large specimen (R=150 mm.) is 35 mm. across and the mouth is ten millimeters in diameter. Each oral (adambulacral) plate carries two or three short spines arranged side by side more or less horizontally, the innermost the longest, the others successively shorter. The actinal surface shows more or less of a tendency to become abruptly and deeply concave at the centre, so that the proximal portions of the ambulacra are almost vertical, the adambulacral spines thus lying horizontally and the oral spines vertically. This tendency is much more marked in some specimens than in others; thus, in a specimen with R=105 mm., the buccal membrane is 20 mm above the horizontal portion of the actinal surface of the rays, while in another specimen with R=150 mm. the depression is no deeper; and in a third specimen with R=48 mm., the vertical distance to the buccal membrane is only five millimeters. As no observations on the living animal have yet been recorded, it is impossible to say whether this buccal depression has any physiological importance or not. It is interesting to note however that in adult specimens where the depression is well marked, the adambulacral spines on its sides are smaller and less prominent, and the pedicels longer and more prominent, than elsewhere on the actinal surface. — Pedicels in a zigzag row on each side of each ambulacrum, scarcely crowded enough to make them quadriserial; proximally in adults and still more so in the young, they are distinctly biserial. Madreporite single; small, slightly convex and irregularly furrowed in young specimens, usually becoming broken up into a number of fragments in adults; even small specimens may show this fragmentation to some extent. — Color [1] of abactinal surface dark (gray, brown, blackish, or black), rarely more or less variegated with

[1] The color of living Heliasters has never been described; in all the descriptions here given, the colors referred to are those of alcoholic and dried specimens.

light colored blotches; spines and madreporite, yellowish or whitish; actinal surface yellowish, the pedicels darker than the spines.

Range. — San Lorenzo and Manta, Ecuador (Rathbun); Payta, Peru (M. C. Z. and U. S. N. M.); Ancon, Peru (Rathbun); Callao, Peru (Meissner); Arica and Iquique, Chili (Plate); Mejillones, Chili (M. C. Z.); Caldera, Chili (M. C. Z); Copiapo, Chili (Leipoldt); Guasco, Chili (Say); Coquimbo and Valparaiso, Chili (Plate). — How far north of the equator this species occurs we have no definite information; but there can be little question that Stimpson's **(1857)** record of it from Mazatlan, Mexico, is based on a specimen of *microbrachius*. It probably does not reach Panama Bay, or the many collectors who have been there would have found it, and by similar argument we may say it does not range to any great distance south of Valparaiso. It has not been taken at any of the outlying islands.[1] We are justified, therefore, in considering its range to be as follows: —

Mainland coast of western South America from northern Ecuador (about 2° N. lat.) to Valparaiso, Chili (33° 2′ S. lat.).

Remarks. — As this is the longest known and the largest species, it is probably most often seen in museums, and most frequently referred to in literature. The compound nature of the madreporite has been spoken of by many writers, but examination of a large series of specimens shows that the madreporite is not different, early in life, from that of Asterias, and not even in adults is it always broken up, for it may remain single and without peculiarities throughout life. Young specimens of *helianthus* usually have the rays much more blunt and less tapering than adults, and the three longitudinal series of spines on the abactinal side of each ray are usually very distinct. — Among the specimens sent me from the National Museum is an interesting individual (No. 21947), about 120 mm. in diameter, and having 32 rays, labelled "Loc.? Albatross, 1888." The further information is given in a list of the Heliasters sent, "Found in bottom of tank; may belong to one of above lots;" the "above lots" referred to are from the Galapagos Islands and the Gulf of California. Although too young to make identification certain, the specimen is apparently a young *helianthus*, as shown by the form and arrangement of the abactinal spines, the madreporite, and the long, free (33–40 per cent) rays. The locality of this specimen is therefore a matter of great interest, for the "Albatross" in 1888 made no shore collections between Lota, Chili (37° S. lat.), and Panama, save at the Galapagos Islands, and all of these places are well outside the known range of *helianthus*.

Material examined: —

15 specimens.	Mejillones, Chili.	M. C. Z. collection.
10 "	Payta, Peru.	" "
23 "	Caldera, Chili.	" "
2 "	"Peru."	" "
?1 specimen	Loc.?	U. S. N. M. "
51 specimens	5 localities.	

[1] Plate's **(1896)** reference to *helianthus* at Juan Fernandez is probably based on specimens of *canopus*.

Heliaster canopus Perrier.

Plate 3, Fig. 2; Plate 8, Fig. 7.

Heliaster canopus Valenciennes. Perrier, 1875.
Heliaster canopus (Val., MS.) Perrier. Sladen, 1889.

There is no good reason why Valenciennes' name should be associated with this species any longer, for his manuscript museum name has no standing. Perrier was the first and only describer of the species.

Description. — Rays, 20–27, averaging (27 individuals) 24; about 53 (47–60) per cent of ray free. R = 30–60 mm.; r = 15–30 mm. Breadth of ray at base, 4–7 mm. R = 7–8 br. Rays somewhat flattened, or a little arched abactinally, rather angular, with blunt and rounded tips. Disc moderately large, flat, or a little arched. Abactinal skeleton rather stout and with small meshes. Abactinal spines numerous, small, rather slender, and not at all capitate, without definite arrangement on disc, but appearing in distinct series on rays. Marginal series of ray contain largest abactinal spines; median series somewhat smaller. Between marginal and median series, a lateral series of very small spines is often present. The marginal series tend to converge as they pass on to the disc, and thus separate the median and lateral rows from the spinulation of the disc; this arrangement is usually evident, but is much more marked in some specimens than in others. — Sides of ray with two or three series of long, compressed spines. Actinal surface essentially as in *helianthus*. Pedicellariae fairly common, especially towards tip of rays abactinally, chiefly forcipate; large forficate ones rather rare and smaller than in *helianthus*. Madreporite usually simple and convex, rarely flattened and fragmented. — Color of abactinal surface deep purplish-black; spines whitish; actinal surface and madreporite yellow; pedicels brownish-yellow.

Range. — Juan Fernandez Islands (M. C. Z.).

Remarks. — This interesting little species is remarkably well characterized, and can be very readily distinguished at a glance. Perrier (1875) thought it possible that it was the young of *helianthus*, but the large series of specimens collected by the "Hassler" has made it possible to show that this is not the case. Young specimens of *helianthus* have more than 30 rays by the time they are 70 mm. in diameter, whereas the largest specimen of *canopus*, 120 mm. in diameter, has only 20, and there is only one specimen with as many as 27. The difference between *canopus* and a young *helianthus* in the abactinal spinulation is well shown on plate 3. Finally, it is important to note that in the larger specimens of *canopus* the reproductive organs are fully developed, showing their sexual maturity in spite of their small size. An interesting point with reference to this species is that 17 of the specimens (or more than 60 per cent) have an even number of rays, whereas in *kubiniji* and *multiradiatus*, the two other species with relatively few rays, only 41 out of 127 (or less than 33 per cent) have an even number. Now in *helianthus* 56 per cent have an even number of rays, and it would seem as though the condition in *canopus* is further confirmation of the view that this

little species is more nearly related to *helianthus* than to the species with relatively few rays.

Material examined: — 27 specimens, Juan Fernandez, M. C. Z. collection.

Heliaster multiradiatus (Gray).

Plate 4, Fig. 1.

Asterias multiradiata Gray, 1840.
Heliaster multiradiatus Dujardin and Hupé, 1862.
Heliaster multiradiata Verrill, 1867.

Description. — Rays 21–27, averaging (10 individuals) 23.8; about 60 (50–70) per cent of ray free. R = 60–100 mm.; r = 25–47 mm. Breadth of ray at base, 6–12 mm. R = 8–10 br. Rays more or less distinctly cylindrical, sometimes slightly flattened and rather angular abactinally, especially near middle. Disc moderate, more or less distinctly and abruptly elevated at centre. Abactinal skeleton moderately stout, reticulate, with rather small meshes. Abactinal spines not very numerous, about 10–16 per sq. cm., moderately stout, high, especially on disc, and more or less cylindrical, sometimes thickened, clavate or capitate at the summit. No evident arrangement on disc, but on rays a median series, with a lateral and marginal series on each side (five series in all), can generally be clearly distinguished, though sometimes there appear to be six series, or again only four. The largest spines are on disc and at base of ray, the smallest near tip of ray; the median series is usually somewhat larger than the others. — Sides of ray with two series of compressed spines, which are usually shorter than the adjoining actinal series. Actinal surface much as in *helianthus* and the other species, but the adambulacral armature is somewhat different, for the large spines do not alternate with small ones, but are practically uniform in size, and on many of the plates a second smaller spine stands on the inner edge, thus making the armature of the furrow double. In some specimens nearly the whole series is double, while in others two spines are to be found only on scattered plates. Occasionally three spines occur on a single plate. The larger spines are about three millimeters long, quite slender, and nearly cylindrical. Outside of the adambulacral series are two rows of actinal spines, the lower of which consists of spines longer and heavier than the adambulacral, while the upper are somewhat smaller. These two series, but especially the lower, extend inward well onto the interbrachial area. Towards the tip of the ray all of the large spines become greatly reduced, so that the 15–17 series which surround the tip are of nearly uniform size, though the adambulacral and adjoining series are still distinguishably larger. Buccal depression as in *helianthus*. — Pedicels not very numerous or crowded, so that they are not truly quadriserial at any point. Pedicellariae mostly small, numerous, especially on abactinal side of rays near tip; sometimes very large forficate pedicellariae occur on the actinal surface. Madreporite rather small, usually simple and convex, very rarely showing any trace of fragmentation. — Color of abactinal surface, light gray, yellowish, or whitish, irregularly blotched with dark gray or blackish; on the rays the dark blotches appear as irregular cross-bands; spines whitish, yellowish, or brownish; actinal surface mostly light yellow or whitish, but interbrachial areas and outer side of large adambulacral spines on proximal half of rays tend to become blackish, and in most specimens there is a striking contrast between the inner and the

outer sides of the adambulacral series, and between the basal and distal halves of each adambulacral spine, on its outer side; oral spines usually dark, at least on aboral side; madreporite white or yellow.

Range. — Hood's Island (Gray); Chatham Island (U. S. N. M.); Albemarle Island (M. C. Z.); Charles Island (M. C. Z.). Confined to the Galapagos Islands. — The reported occurrence of this species in the Hawaiian Islands is to be accounted for as follows: — In 1867 Verrill described a specimen of *kubiniji*, which he said was obtained with other Panamic species from Mr. Pease at the Sandwich Islands, but probably came from Acapulco or Mazatlan, Mexico. Perrier (**1878**), ignoring or failing to understand the latter half of Verrill's statement, gives "Iles Sandwich" as one of the localities for *kubiniji*. Sladen (**1889**), accepting Rathbun's view that *kubiniji* is a synonym of *multiradiatus*, and also evidently accepting Perrier's list of localities at its face value, gives Sandwich Islands as a habitat of *multiradiatus*. On the strength of Sladen's word, Fisher (**1906**) includes *H. multiradiatus* in his list of Hawaiian starfishes, but he very properly expresses serious doubt as to any Heliaster occurring at Hawaii.

Remarks. — Verrill (**1867**) in speaking of *kubiniji* pointed out that Gray's description of *multiradiatus* did not fit specimens from Mexico, and the two species were regarded as distinct until Rathbun (**1887**) compared two specimens from Chatham Island with a large series from Mexico, and reached the conclusion that they were identical, and that *kubiniji* was therefore a synonym of *multiradiatus*. Sladen (**1889**) adopted that conclusion, and it has since been very generally accepted. In 1895 Leipoldt, referring to five specimens from Chatham Island, describes what he calls their "peculiar" coloration, his specimens agreeing well with typical *multiradiatus*, the coloring of which had never previously been described, for curiously enough neither Gray nor Rathbun make any reference to the color. Dr. Rathbun has kindly sent me, among the Heliasters from the National Museum, the two specimens from Chatham Island, on which his opinion was based. I find they agree in all essentials with the other Galapagos specimens before me, and there will be no question that to them belongs the name *multiradiatus*. After a comparison of these specimens with a very large series of *kubiniji* from Mexico I am obliged to disagree with Rathbun's conclusion that they are all one species. No one will question the close relationship between the Galapagos and Mexican forms, and it is simply a matter of personal opinion whether it is better to emphasize the relationship by uniting them under one name, or to emphasize by distinct names the differences which have arisen in completely separated geographical areas and which are obviously and reasonably constant. The latter course seems to me preferable. The differences between the two can better be discussed under *kubiniji*, and only one or two other points need to be referred to here. Both species show great diversity in the length of the different rays in a single individual, old specimens often having only two or three rays of exactly the same length. As an illustration of this fact, the following measurements (in millimeters) of the 25 rays of an excellent specimen of *multiradiatus* may be given, beginning with the ray to the left of the madrepore and going clockwise: 72, 71, 70, 69, 51, 57, 65, 68,

64, 67, 73, 68, 71, 69, 72, 40, 42, 71, 66, 44, 75, 74, 72, 45, 66. Of the 25 rays, one is 75 mm., one is 74, one is 73, three are 72, three are 71, one is 70, two are 69, two are 68, one is 67, two are 66, one is 65, one is 64, one is 57, one is 51, one is 45, one is 44, one is 42, and one is 40 mm. long. Besides this diversity in length, it is not an easy matter to say just what proportion of the ray is free, for, while of one ray 70 per cent may be free on one side and 65 on the other, another ray may be only 50 per cent free on each side. To determine the point satisfactorily four or five of the longest rays should be measured, the measurements added together and divided by four or five, as the case may be, the quotient being the average R. Then measure the free portion on each side, add, and divide by eight (or ten), the quotient being the average free portion. Dividing this by the average R gives the percentage of ray that is free. Adopting this plan for one of the best specimens of *multiradiatus*, we get these figures: —

$$83 + 83 + 82 + 76 + 80 = 404 \text{ mm.} \div 5 = 80.8 \text{ mm.} = \text{R}.$$

$$50 + 51 + 50 + 53 + 46 + 44 + 47 + 48 + 46 + 45 = 480 \text{ mm.} \div 10 = 48 \text{ mm.} = \text{free portion.}$$

$$48 \div 80.8 = .59 \therefore 59 \text{ per cent of ray is free.}$$

With the other five species of Heliaster it is not necessary to go to such trouble, as all the rays are, in normal specimens, of approximately the same length. — The specimens of *multiradiatus* from Chatham Island are notable for the large abactinal spines, which are as heavy as in most specimens of *kubiniji*. One of the specimens is further remarkable for the fact that although very large (R = 100 mm.) there are only 15 developed rays and two of these are very small; there is also a very rudimentary ray 6 mm. long, at one point on the abactinal surface. Careful examination shows that this individual was at some time badly injured, nearly bisected in fact, and has only imperfectly made up its loss.

Material examined: —

3 specimens.	Albemarle Island.	Leland Stanford Jr. Univ. collection.
5 "	Charles "	M. C. Z. "
2 "	Chatham "	U. S. N. M. "
1 specimen	Albemarle "	M. C. Z. "
11 specimens.	3 localities.	

Heliaster kubiniji Xantus.

Plate 4, Fig. 2; Plate 5, Fig. 2; Plate 6, Fig. 1: Plate 7, Figs. 8–10; Plate 8, Figs. 1–6.

Heliaster kubiniji Xantus, 1860.
Heliaster Kubiniji Verrill, 1867
Heliaster Kubinjii Lütken, 1871.
Asterias Kubinjyi Lütken, 1872.
Heliaster Kubingii Rathbun, 1887.
Heliaster Kubinijii Ives, 1889.

Description. — Rays 21–28, averaging (90 adults) 23; about 47 (40–55) per cent of ray free. R = 60–107 mm.; r = 30–60 mm. Breadth of ray at base, 6.5–15

mm. R = 6½ – 9½ br. Rays more or less cylindrical, sometimes slightly flattened and angular abactinally, but usually tapering more sharply than in *multiradiatus*. Disc moderate, more or less distinctly and abruptly elevated at centre. Abactinal skeleton and spines as in *multiradiatus*, but median and lateral series of spines on ray more distinct, usually with more numerous, and stouter and more capitate spines. Space between lateral and marginal series wider than between lateral and median, and usually conspicuous. Spines on disc often very stout and much thicker at top than at base, sometimes two to two and one half millimeters across, not infrequently with the broad tip distinctly concave and more or less notched in the margin. — Sides of ray and actinal surface as in *multiradiatus*, except that the spines of the series outside the adambulacral row are much stouter, and are often compressed and truncate or even clavate. The actinal aspect of the ray is thus quite as different in the two species as the abactinal. Pedicellariaè, pedicels, and madreporite, as in *multiradiatus*. — Color of abactinal surface deep purplish-black; spines more or less deep yellow; pedicellariae yellowish, often so numerous as to give the distal half of the ray a nearly uniform yellow color; occasionally the rays have a banded appearance as in *multiradiatus*, but not so distinct as in that species, and seemingly due in large part to unequal distribution of the pedicellariae; actinal surface deep yellow with pedicels very dark, often blackish; adambulacral spines often blackish at base on the outer side, and those near mouth are sometimes very dark for their whole length; madreporite deep yellow.

Range. — San Luis Gonzales Bay, Lower California; Guaymas, Mexico; and San Juan, L. C. (U. S. N. M.); Margarita Bay, L. C. (Perrier); Magdalena Bay, L. C. (Ives); Puerto Balandia, La Paz and Pichilingue Bay, L. C. (U. S. N. M.); Altata, Mexico (Lutken); Mazatlan, Mexico (M. C. Z.); Cerro Blanco, Cape St. Lucas, L. C. (U. S. N. M.); Acapulco, Mexico (M. C. Z.); and Macuoha, Nicaragua (Ives). — A specimen in the National Museum labelled "Guanajuato, Mexico," was probably purchased by the collector in that inland city at a curiosity shop. Another specimen labelled "Colorado Desert" is badly worn, as though by sand, and looks as though it might have been picked up in the desert, though how it came there would be hard to decide. — There seems to be no record for this species south of Nicaragua, so that its range is apparently confined to the western coast of Central America and Mexico, between 10° and 30° N. lat.

Remarks. — This is a very easily recognized species, as the small number of rays, free for nearly half their length, the large abactinal spines and the coloration combine to distinguish it at a glance from all, except *multiradiatus*. From that species it is separated not merely by the color, which is quite distinctive, but especially by the appearance of the rays, which are less slender, less largely free, and have stouter spines. The differences are all shown in the figures given (Plate **4**), where even the contrast in color is plainly indicated. Yet *kubiniji* shows great diversity even in specimens from one locality, the spines on the abactinal surface, particularly those forming the median series on the rays, varying greatly not only in actual but in relative size. There is also much variety in the relative breadth of the rays, but it must be admitted that it is only small specimens (R = less than 70 mm.) which have the rays more than 8 times as long as thick. There is

less diversity in color, for although the rays are sometimes transversely banded, *kubiniji* is always darker than *multiradiatus*, the yellow being much deeper, often becoming quite brown. Comparatively little variation in the amount of ray that is free is shown, the very great majority of specimens having half or a trifle less.

Material examined: —

42	specimens.	Acapulco, Mexico.	M. C. Z.	collection.
20	"	Mazatlan, "	"	"
5	"	Loc.?	"	"
15	"	Cape St. Lucas, L. C.	U. S. N. M.	"
16	"	Pichilingue Bay, L. C.	"	"
5	"	"Lower California."	"	"
4	"	La Paz, L. C.	"	"
3	"	Guaymas, Mexico.	"	"
2	"	San Luis Gonzales Bay.	"	"
1	specimen	"Gulf of California."	"	"
1	"	San Juan, L. C.	"	"
1	"	"Guanajuato, Mexico."	"	"
1	"	"Colorado Desert."	"	"
116	specimens.	13 localities.		

Heliaster microbrachius Xantus.

Plate 1; Plate 7, Fig. 11.

Heliaster microbrachia Xantus, 1860.
Asterias helianthus Stimpson, 1857. ?
Asterias microbrachia Lütken, 1871.
Heliaster microbrachius Leipoldt, 1895.

Description. — Rays 27–44, averaging (37 individuals) 34.7; about 25 (20–30) per cent of ray free. R = 60–125 mm.; r = 45–95 mm. Breadth of ray at base 8–15 mm. R = 7–8 br. Rays more or less flattened abactinally, tapering rather sharply to a blunt point. Disc very large, somewhat elevated in well-preserved specimens, but not abruptly so. Abactinal skeleton stout, closely reticulated, with small meshes. Abactinal spines very numerous, 35–50 or even more per sq. cm., small, usually low, more or less cylindrical and without definite arrangement. In some large specimens the spines show a slight tendency to be capitate, and in many cases they are very evidently compressed. In some individuals the spines on the rays form five fairly distinct series, and these can be followed inward for a variable distance onto the disc. At the edge of the disc the marginal series of adjoining rays are sometimes very clearly separated by a bare space about 2 mm. broad, but in full-grown specimens this arrangement is not usually distinct. — Sides of ray with two series of compressed spines. Actinal surface very much as in *helianthus*, but pedicellariae are as a rule less frequent, and the reduction of the adambulacral armature reaches its extreme, for in large specimens only every other adambulacral plate bears a spine until the distal half or even third of the furrow is reached, and even at the extreme tip of the ray it is rare to find a plate with two spines. — Pedicels rather numerous, distinctly quadriserial at the middle of the ray. — Madreporite rather small, often concave, and usually fragmented. — Color of abactinal surface purplish- or grayish-black; spines deep yellow or whitish; actinal surface whitish,

yellowish, or brownish, with pedicels much darker than spines; madreporite brown.

Range. — Asuncion Island and Cape St. Lucas, L. C. (U. S. N. M.); Margarita Bay, L. C. (Perrier); Magdalena Bay, L. C. (Ives); Lequina Bay, L. C. (M. C. Z.); La Paz, L. C. (Perrier); Altata, Mexico (Lütken); Mazatlan and Acapulco, Mexico (M. C. Z.); Panama (M. C. Z.); and Pearl Island, Panama (Verrill). — Ives (1889) lists a specimen from Chili, and there is a dried specimen in the collection of the Museum of Comparative Zoölogy labelled "Chili, Hassler Expedition." The latter agrees perfectly with the numerous dried specimens from Acapulco, collected by the "Hassler," and I have no doubt it is one of the same lot, which has received an erroneous label by mistake. It is probable that the Philadelphia specimen, if it is really *microbrachius*, is to be accounted for in a similar way. — The range of this species seems to be along the coast of Central America and Mexico between the parallels 8° and 27° N. lat., thus nearly coinciding with that of *kubiniji*, but extending somewhat further south.

Remarks. — This species is so easily recognized, when adult, that its standing can scarcely be questioned, yet the young are often quite perplexing, for even when 70–80 mm. in diameter, they may have the rays quite long and slender, and free 30–35 per cent of their length. The small, slender, and numerous abactinal spines, however, make even these young ones recognizable. There are usually 35 or 36 rays, and I have seen only one specimen with more than 40, though curiously enough that one has 44. There are only two specimens before me with less than 30 rays, and of these the one with 27 is not quite full-grown, as R is less than 60 mm.

Material examined: —

32 specimens.	Acapulco, Mexico.	M. C. Z. collection.
1 specimen.	Lequina Bay, L. C.	" "
1 "	Mazatlan, Mexico.	" "
1 "	"Panama, Pacific side."	" "
1 "	"Pacific Coast of Mexico."	" "
1 "	"Chili."	" "
1 "	La Paz, L. C.	U. S. N. M. "
2 specimens.	"West Coast Central America or Mexico."	" "
40 specimens.	8 localities.	

Heliaster cumingii (Gray).

Plate 5, Fig. 1.

Asterias Cumingii Gray, 1840
Asterias solaris Carpenter, 1856. ?
Heliaster Cumingii Dujardin and Hupé, 1862.
Asterias Cummingii Lütken, 1872.
Heliaster cumingi Clark, 1902.

Description. — Rays 32–40, averaging (34 adults) 35.6; about 23 (15–30) per cent of ray free. R = 55-90 mm.; r = 40-73 mm. Breadth of ray at base, 7–12 mm.

R = 7–8 br. Rays more or less flattened, both actinally and abactinally, tapering abruptly to a blunt point so that the free portion is nearly triangular; the length of the triangle is a little greater than the breadth, while the distance between the tips of any two rays about equals the breadth of a ray. Disc very large, somewhat elevated at the centre but very gradually. Abactinal skeleton very stout with small meshes. Whole abactinal surface covered more or less uniformly, but not very thickly (15–20 per sq. cm.), with nearly cylindrical, rather stout spines, one to two millimeters long. These spines are not usually capitate, but in some specimens many of them are. On the margin of the disc and bases of the rays, the spines show some tendency to arrangement in radial series with three series to a ray, but when this arrangement is most evident, the spines in each series are noticeably few and those in the lateral series are very conspicuous. — Sides of ray with one or two series of compressed spines. — Actinal surface much as in *helianthus*, but the interbrachial areas are more extensive and have numerous papulae. Adambulacral and other spines more or less variable, not essentially or constantly different from those of *helianthus;* owing to the greater fusion of rays, and consequent increase of the interbrachial areas, the series of spines outside the adambulacral extend further inward. Buccal depression and membrane as in *helianthus*. Pedicellariae very small, both forficate and forcipate present, but the latter are more abundant and are most abundant on rays abactinally. The pedicellariae are infrequent, and often seem to be entirely wanting on the actinal surface. — Pedicels in a zigzag row on each side of the ambulacrum, so crowded near middle of ray as to be quite distinctly quadriserial there. — Madreporite as in *helianthus*. — Color of abactinal surface deep bluish-black; spines (at least at tip) light brown, yellow, yellowish, or whitish; actinal surface whitish or yellowish, with pedicels darker than spines and papulae; madreporite brownish or blackish.

Range. — Hood's Island (Gray); Chatham Island (U. S. N. M); Abingdon Island (U. S. N. M.); Albemarle Island (M. C. Z.); Charles Island (M. C. Z.). — This species is confined to the Galapagos Archipelago, and apparently occurs throughout the group.

Remarks. — As the type of *cumingii* is lost, it would be impossible to decide to what form that name ought to be applied, were it not that the locality given by Gray, with his brief description, leaves no doubt that the short-rayed Heliaster of the Galapagos is the species he had before him. As Gray's description is so brief, it was very natural that Verrill (1867) should say of his Peruvian specimens that they "are, perhaps, the species described by Gray." When Peruvian and Galapagian specimens are laid side by side, however, the difference between them is usually very noticeable, and, as previously stated, I have felt justified in calling them by different names, for the following reasons: — (1) The differences between them are obvious and uniformly associated with locality. (2) These differences are quite constant, and connecting forms are wanting or very rare. (3) The geographical isolation of the Galapagian form is very complete, Heliaster being so exclusively littoral. (4) In no other way can the differentiation of the Galapagian Heliasters be so well emphasized. Nevertheless it is freely admitted that there is room for difference of opinion as to the wisdom of this course, for the probable existence of connecting links among Galapagian specimens would cause

some zoölogists to make use of a subspecific name, while others might not consider the differences sufficiently great and constant to warrant any attempt to distinguish the two forms by name. Although the large series of specimens before me, 101 in all, have made it possible to compare the two forms very carefully, the only apparent connecting links I have seen are from the Galapagos. None of the 53 Peruvian specimens show any intermediate characters or offer any difficulty in assigning them to the mainland form. Of the 48 Galapagian specimens, those (6) in the collection of the Leland Stanford Junior University are all unmistakably *cumingii*, and the same is true of five of those in the collection of the Museum of Comparative Zoölogy. There are two young ones, however, in the latter collection, one 44 mm. in diameter, the other about 80, which are less easily determined. The former is of course too young to show any specific characters clearly, while the larger one has the abactinal spines coarser and more nearly capitate than in most Galapagian specimens. However, as Rathbun **(1887)** has pointed out, the young quite commonly have more capitate spines than the adults. Of the 38 specimens of Heliaster, supposedly from the Galapagos Islands, sent me from the National Museum, two are evidently *multiradiatus* (as already mentioned) and 17 are typical *cumingii*, while four others are too young to show specific characters. Of the remainder, nine are evidently *cumingii*, but resemble the Peruvian species in the conspicuously capitate spines, especially along the margins of the rays. The other six specimens demand a special word for each.

1 and 2. Under No. 21947 are two specimens, one of which seems to be a young *helianthus* and has been referred to under that species. The other is similarly labelled from an unknown locality, but is much larger, 150 mm. in diameter. It is apparently *cumingii*, though the spines on the abactinal surface of the rays are decidedly capitate. It probably came from the Galapagos.

3. Under No. 15523 is a young individual, about 72 mm. in diameter, labelled "Heliaster cumingii Gray. Chatham Island, Galapagos. Dr. W. H. Jones, U. S. N." It seems to be correctly identified, but the rays are free for an unusual proportion (35 per cent) of their length, giving the specimen a peculiar appearance, somewhat like *helianthus*.

4. No. 15524 is a large specimen, about 145 mm. in diameter, labelled "Chatham Island, Galapagos," and bears a striking resemblance to *microbrachius*. It has been so well and fully described by Rathbun **(1887)** that no description need be given here. This individual represents the extreme development of the peculiar characters of *cumingii*, except that the abactinal spines are unusually numerous.

5 and 6. Under 21948 are two specimens, about 145 mm. in diameter, concerning which we have only the information that they were collected by the "Albatross" in 1888, "Loc. ?" One of them is very similar to the Peruvian form, as the abactinal spines are very numerous, while the other, although similar, is more like Galapagian specimens. If these individuals are from the Galapagos Islands, they are apparently connecting links with the mainland form.

The young of *cumingii* not only have the free portion of the rays relatively longer than in the adult, but the abactinal spines are lower, stouter, and more capitate. Specimens under 75 mm. in diameter do not show the specific char-

acters clearly, and cannot always be distinguished certainly from mainland Heliasters of the same size. So far as the material at hand is concerned, the specimens from the different islands of the archipelago are quite indistinguishable, with the single interesting exception of the specimen from Abingdon Island. This individual is not adult, but has 35 rays and is unusually well preserved. The rays are remarkably slender, much as they are in some very young specimens of *microbrachius*. When compared with a specimen of the same size from Charles Island, the peculiarities of this Abingdon Island individual are well brought out.

Locality of Specimen.	R.	Free portion of ray.	Per cent free.	Breadth of ray at base.	Breadth in R.	Breadth in free portion of ray.
Charles Island	46 mm.	10 mm.	22	6 mm.	7.7 times	1.6 times
Abingdon Island	44 "	11 "	25	4 "	11 "	2.7 "

Material examined: —

6 specimens.	Albemarle Island.	Leland Stanford Jr. Univ.	Collection.
25 "	" "	U. S. N. M.	"
1 specimen.	" "	M. C. Z.	"
1 "	Abingdon "	U. S. N. M.	"
6 specimens.	Charles "	M. C. Z.	"
6 "	Chatham "	U. S. N. M.	"
?3 "	Loc.?	"	"
48 specimens	5 localities		

Heliaster polybrachius, sp. nov.

Plate 2, Fig. 2; Plate 7, Fig. 12; Plate 8, Fig. 8.

Heliaster Cumingii Verrill, 1867a, p. 291; 1867b, p. 33, line 10, 334 and 344.
Perrier, 1878, p. 11 and 99.
Leipoldt, 1895.

Description. — Rays 31–43, averaging (38 adults) 37.1; about 18 (14–23) per cent of ray, free. R = 55–90 mm.; r = 45–77 mm. Breadth of ray at base, 9–11 mm. R = 6–8 br. Rays much as in *cumingii*, but free portions stouter as a rule, with more convex sides and blunter tip. Disc as in *cumingii*, but abactinal spines much more numerous, especially on the region where disc and rays join, 25–50 per sq. cm. Marginal series of spines on rays very distinct, but not usually noticeably larger than other abactinal spines. All of the abactinal spines are commonly low, of nearly uniform height, and more or less distinctly capitate.[1] Actinal surface as in *cumingii*, but pedicellariae are commonly abundant among the adambulacral and adjoining spines. Pedicellariae all small, as in *cumingii*. Buccal depression, pedicels, and madreporite also as in *cumingii*. — Color of abac-

[1] Leipoldt (1895) refers to a specimen in which the abactinal spines were three millimeters high, but none of the specimens before me have any over two, and they are commonly about one millimeter high.

tinal surface dull greenish, blackish, or black, often variegated with yellowish blotches; sometimes the appearance is that of a yellowish background with a few small blackish blotches; spines and actinal surface yellowish; pedicels and madreporite brownish.

Range. — Zorritos, Peru (Verrill); Payta, Peru (M. C. Z.); Chili (M. C. Z.). — The distribution of this species seems to be curiously limited, for while it appears to be very common at Payta, Zorritos is the only other port from which it is recorded. Aside from the specimens from Payta, there is a single poor and old specimen in the Museum of Comparative Zoölogy labelled "Chili," but nothing further is known of its origin.

Remarks. — The differences between this species and the preceding may be briefly summarized as follows: — In *polybrachius* the rays are more numerous, averaging more than 37 as against 35.6 in *cumingii*, and the free portion is shorter, stouter, and more bluntly pointed; the abactinal spines are much more numerous (25–50 per sq. cm. where thickest), lower and more capitate, and pedicellariae are usually abundant on the actinal surface, while in *cumingii* they are often wanting; the color of *polybrachius* is often lighter than that of *cumingii*, and the Peruvian specimens are frequently variegated abactinally with yellowish. The most obvious of these differences are well brought out in the figures given on plate **2**. Doubtless there is room for wide difference of opinion as to the significance of these differences, and whether they are important enough to entitle the Peruvian form to a separate name. There are three possible courses, any one of which we might follow: — (1) We might call the Peruvian specimens *cumingii*, and simply point out the features in which they differ from Galapagian specimens; (2) we might call them a subspecies of *cumingii*, and make use of a trinomial name for them; (3) we might regard them as a distinct species. I have already given (p. 52) the reasons which lead me to consider the third of these possible courses the best, but I am free to admit that *polybrachius* and *cumingii* are so closely related that were they both found on the same coast I should consider it unwise to attempt to separate them. It seems to me clear, however, that one is an offshoot of the other, and the facts already given under *cumingii* with reference to the variability of the island specimens seem to show that that species is the offshoot from *polybrachius*, as the geographical distribution of the two forms would lead us to expect. The offshoot, however, is the one which has borne a name for over sixty years, while the parent stock has remained nameless. In selecting a name for it *polybrachius* has been chosen because the average number of rays is greater than in any other species of Heliaster.

Material examined: —

51 specimens.	Payta, Peru.	M. C. Z. Collection.
1 specimen.	"Peru."	" "
1 "	"Chili."	" "
53 specimens.	3 localities.	

THE NUMBER OF RAYS AND THE ORDER OF THEIR SUCCESSION.

The large number of rays in Heliaster is one of the most interesting features of the genus, but owing to the scarcity of material almost nothing has been done in the way of investigating the amount of variability in this character or the order in which the successively new rays appear. In 1872, Lütken showed that there is no correlation between size and the number of the rays in Heliaster, after a certain size (about 100 mm. in diameter), which we may call that of maturity, is reached; that is to say, very small specimens have a relatively small number of rays and this number increases with increasing size, only until the animal is approximately mature, after which there may or may not be a continued addition of new rays. Having only 15 specimens (*H. helianthus*) for comparison and only one of those less than 75 mm. in diameter, Lütken did not attempt to discuss the original number or the sequence of the rays, but it is hard to understand how any one could examine his data and not see that the number of rays certainly does increase after larval life and even after the starfish is 50 mm. across. Rathbun (1887) in his report on Heliaster makes statements in regard to *cumingii* which indicate his belief that the rays increase in number with increasing age (see p. 441, line 8). In spite of these writers, however, Perrier, as late as 1893, states that Labidiaster is the only starfish in which additional rays develop after the larval period is passed and the adult form assumed. In 1895, Leipoldt referred to the presence of two young rays in a specimen of *H. cumingii* (=*polybrachius*), about 50 mm. in diameter, which had otherwise only 24 rays. In 1900, Ritter and Crocker showed conclusively that Pycnopodia begins its post-larval life with only six rays, and that the additional 14–18 rays are in process of appearance, normally in pairs, until well into adult life. There can no longer be any question therefore that starfishes with twenty or more rays begin their post-larval life with a much smaller number and continue to add new rays for an undetermined period. Consequently specimens of Heliaster with fewer than twenty rays are sure to be met with and if age and size are disregarded, we cannot assign on *à priori* grounds the minimum number which a starfish of this genus may show. The smallest specimen among the 346 examined measures only 20 mm. in diameter, and I can find no published record of any specimen nearly as small. It is a young individual of *kubiniji* (U. S. N. M. No. 21950) from Lower California and has 12 rays, eight well developed, three much smaller and a twelfth barely started. With it are two other specimens, 25 mm. in

diameter, with 13 and 14 rays respectively. Another specimen of the same species from Guaymas, Mexico (U. S. N. M. No. 21949) is also 25 mm. in diameter but has 15 rays. A larger one (110 mm.) from the same place (U. S. N. M. No. 21941) has only 17 rays, of which two are very small; but this specimen like the individual of *multiradiatus* referred to on p. 48, which, although 200 mm. in diameter, has only 16 rays, is almost certainly the victim of an unusual accident. A specimen of *kubiniji* 64 mm. in diameter, from Acapulco, Mexico, (M. C. Z., No. 1171), has only 18 rays. I have neither seen, nor found a record of, a specimen of any species with 19 rays. The largest specimen of *canopus*, 120 mm. in

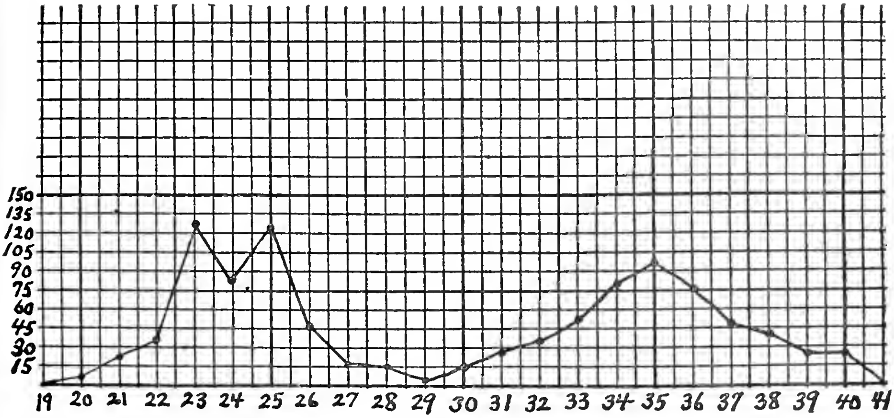


DIAGRAM 1[1].

To show the relative abundance (per thousand, regardless of species) of Heliasters with 20–40 rays. Based on 335 individuals.

diameter, and the smallest of *polybrachius*, 40 mm., have only 20 rays each. Above 20, all numbers occur up to 44, but I have seen no specimen with 41. There are eight specimens with 40 rays each (five of *polybrachius*, one of *cumingii*, one of *microbrachius*, one of *helianthus*); one *polybrachius* has 42, one *polybrachius* has 43, and one *microbrachius*, only 140 mm. in diameter, has 44. The number of specimens with from 20 to 40 rays inclusive is 335 and Diagram 1, based on this series, shows the number of individuals in a thousand having any given number of rays between 19 and 41.

A single glance at this diagram shows that there are two groups of Heliasters, one of which tends to have 23–25 rays, and the other 35, and

[1] In this and all the following diagrams: Horizontal lines show the number of individuals. Vertical lines show the number of rays.

that the two are almost completely separated from each other, since individuals with 29 rays are very rare. It is also clear that the group with fewer rays varies less from the normal number than does the other. It is worth while therefore to examine the species separately (omitting the obviously young) to bring out the difference in variability. As *cumingii* and *polybrachius* are so closely allied, they may be considered together, especially as there is no essential difference between them when tabulated separately. We will omit *multiradiatus* altogether as the number of available specimens is too few to make a reliable tabulation possible.

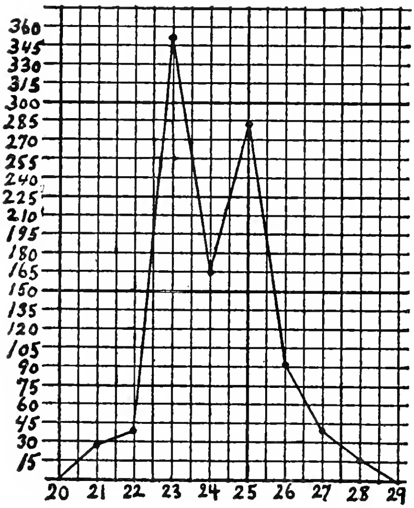


DIAGRAM 2.

To show the relative abundance per thousand, of *H. kubiniji* with 21-28 rays. Based on 110 individuals.

The diversity in the number of rays in *kubiniji* is remarkably slight and is clearly shown in Diagram 2, from which it will be seen that practically 80 per cent have 23–25 rays and that nearly 69 per cent have an odd number. In *canopus* on the other hand (Diagram 3) only 48 per cent, have 23–25 rays, and only 37 per cent have an odd number. Although the small number of specimens available for comparison undoubtedly accounts in part for these peculiarities of *canopus*, it can hardly be doubted that this species shows a much greater tendency to variability in the number of rays than does *kubiniji*. In *helianthus* (Diagram 4) the number of rays varies from 30 to 40 but 64 per cent have 34–36 rays, while only 46 per cent have an odd number. In *cumingii* and *polybrachius* (Diagram 5) the number of rays ranges from 29–40 [1] and only about 36 per cent have 34–36, while almost exactly half have an odd number. The great variability of these two short-rayed species is especially notable in view of the fact that *microbrachius*, which is also short-rayed, agrees strikingly with *helianthus*, 63 per cent of the

[1] The two specimens of *polybrachius* with 42 and 43 rays respectively are omitted from the diagram.

specimens having 34–36 rays, and only 42 per cent have an odd number.

Turning now from the amount of variability to the method of formation of new rays and the order of their appearance, we are favored by the fact that in Heliaster the stomach is provided with five pairs of conspicuous muscles attached to the ambulacral plates of five of the rays, as in Asterias, and comparison of numerous specimens of all ages leaves no doubt that these five rays are, as one would naturally suppose, the original rays of the starfish on first assuming the adult form. This arrangement is strikingly different from that shown by Pycnopodia, where Ritter and Crocker (**1900**) found that the post-larval life apparently starts with six rays. The youngest available Heliaster (*kubiniji*), 20 mm. in diameter, has 12 rays but only eight of these are at all nearly equally developed and it is fair to assume that their arrangement represents the normal condition in an 8-rayed young Heliaster. Numbering the five original rays clockwise from the madreporite, as the specimen is looked at from above, we find there is an accessory ray between rays 1 and 2, 2 and 3, 3 and 4. (Plate **8**, fig. 1). Adding now the four very young rays, in the positions where they occur, we find there are now three between 1 and 2, two between 2 and 3, two between 3 and 4, but there are still no rays between 4 and 5 or between 5 and 1 (Plate **8**, fig. 2). In another young individual (*kubiniji*) with 15 rays, we have the condition shown in fig. 3 (Plate **8**), where it may be seen that although there is now a ray between 4 and 5, 5 and 1 are still side by side. The youngest *polybrachius* has 20 rays, four of which are, however, very small; in this specimen there are three well-developed rays between 1 and 2 and also between 3 and 4, and 4 and 5, while there are only two between 2 and 3 and none between 5 and 1. On adding the four rudimentary rays, it is rather surprising to find that the conditions in the interradii 2 and 3 and 5 and 1 are not changed, but

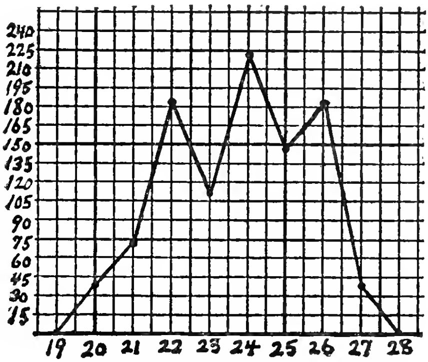


DIAGRAM 3.

To show the relative abundance per thousand, of *H. canopus* with 20–27 rays. Based on 27 individuals.

there are now five accessory rays between 4 and 5, and four in each of the interradii 1–2 and 3–4. The specimen of *canopus* with 20 rays differs only in that there are three rays in interradius 2–3, and only four in 4–5. An example of *kubiniji* with 21 rays gives the condition shown in figure 4 (Plate 8), but specimens of *canopus* with 21 rays are quite unlike this; one has six rays in 1–2, three in 2–3, four in 3–4, three in 4–5, and none in 5–1, and the other has four, three, five, four, and none, in the same order. Very similar to the latter is another *canopus* with 22 rays arranged 4, 4, 5, 4, 0. Specimens of *kubiniji* with 23 and 25 rays show the sequence given in figures 5 and 6 (Plate 8). The order 5, 5, 5, 3, 0, seems to be the normal arrangement for specimens of *kubiniji* with 23 rays, but in a specimen of *canopus*, the order is 5, 3, 5, 5, 0. With 24 rays the order in *kubiniji* is 5, 5, 5, 4, 0, while in an example of *canopus* it is 5, 3, 5, 6, 0. With 25 rays, *canopus* and *polybrachius* both agree with *kubiniji* in the symmetrical 5, 5, 5, 5, 0, and as this was found to be true of all of the six Heliasters having 25 rays, which were examined, it is fair to consider it the normal arrangement. In examples of *canopus* and *kubiniji* with 26 rays each, the additional ray occurs in interradius 1–2. In examples of the same species having 27 rays interesting conditions, undoubtedly abnormal, were found; in *canopus* (Plate 8, fig. 7) there are two rays in interradius 5–1, the only case, among 30 Heliasters examined, in which there are accessory rays in that interradius; in *kubiniji*, the stomach-muscle of 1 is missing, so that there are only four such muscles and the sequence of the rays is 9, 4, 6, 3, 0, with, of course, possible errors in the 9 and 0. After the number of rays gets beyond 26, there appears to be no uniformity in the order or position of the accessory rays, as is clearly shown by the following table: —

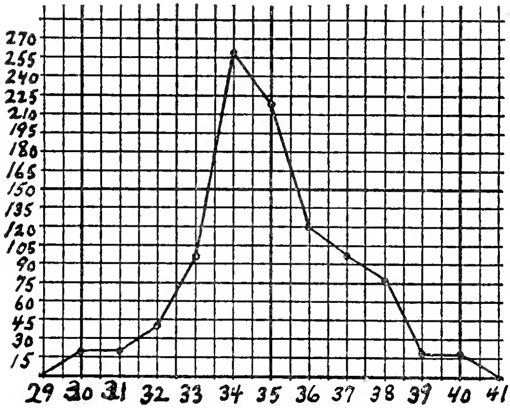


Diagram 4.

To show the relative abundance per thousand, of *H. helianthus* with 30–40 rays. Based on 50 individuals.

Species.	Number of Rays.	Sequence in the Five Interradii.
canopus	27	6, 5, 5, 4, 2. (Plate **8**, Fig. 7.)
kubiniji	27	9, 4, 6, 3, 0.
polybrachius	27	5, 5, 7, 5, 0.
microbrachius	31	8, 6, 7, 5, 0.
polybrachius	31	7, 5, 8, 6, 0.
helianthus	33	8, 5, 7, 8, 0.
helianthus	34	8, 7, 7, 7, 0.
helianthus	35	8, 7, 7, 8, 0.
microbrachius	35	8, 8, 7, 7, 0.
polybrachius	35	8, 7, 8, 7, 0.
polybrachius	37	8, 7, 9, 8, 0. (Plate **8**, Fig. 8.)

The first indication of a new ray in Heliaster, which can be seen without a microscope, is an internal one, simply the gradual separation of the two halves of an interbrachial wall, close to the discobrachial wall.

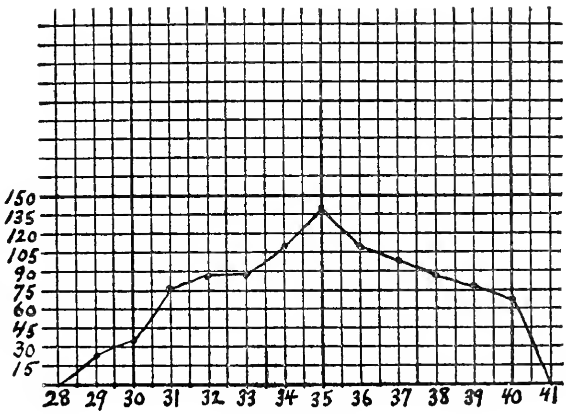


DIAGRAM 5.

To show the relative abundance per thousand, of *H. cumingii* and *H. polybrachius* with 29–40 rays. Based on 88 individuals.

There can be little reason to doubt that the actual first step in the new ray formation is the pushing out of a bud from the outer side of the circumoral, watervascular canal, and the growth of this bud with its attendant tissues is the cause of the separation of the halves of the interbrachial wall; the bud itself becoming the radial water vessel. There is no direct evidence in support of this hypothesis, but it is reasonable, in line with the indirect evidence and open to no serious objection. After

the splitting of the interbrachial wall begins, it goes on more rapidly, if development is normal, towards the actinal surface, and the interbrachial tissues there soon separate and the pedicels of the new ray appear. The growth of the new ray forces the older rays on either side further and further apart until they are entirely separated, and the accessory ray takes its normal place between them. The growth of the new ray in length is more rapid than its increase in diameter, so that it is relatively more slender than the older rays. In many cases, owing to some obstacle, probably an unusually firm calcification of the interbrachial wall, the new ray fails to split that wall actinally and so is forced to grow upward and appear on the abactinal surface. Its subsequent growth may force the walls apart and it then settles down into its proper place and becomes a normal ray. Often, however, the interbrachial wall fails to yield and consequently the new ray is unable to develop, but remains as a rudiment on the abactinal surface, usually near the boundary between the true disc and the bases of the rays. Such rudimentary abactinal rays are by no means rare and may attain quite a size, although usually very small. The largest that I have seen is on a specimen of *cumingii* (U. S. N. M. No. 15523) 170 mm. in diameter; it is 23 mm. long and seven in diameter, with the base about 30 mm. from the centre of the abactinal surface of the disc; it is also remarkable in that the tip is turned in towards the disc, as though one side had grown very much more than the other. Usually such an abactinal ray is situated between two normal rays, but not very rarely it is directly over a normal ray. Two explanations of this position suggest themselves; the aborted ray may have been forced into its present position by the growth of one of the normal rays, or a later bud has developed a normal ray where the aborted ray failed. — A comparison of the above given description of ray formation in Heliaster with Perrier's (**1891**) account of the same process in Labidiaster reveals such similarity as to leave no doubt that the process is identical in the two genera. It may be added that Perrier's figures could be duplicated from specimens of Heliaster, were it necessary, excepting only those showing regeneration. Cases of regeneration occur in Heliaster, but are not very common. Occasionally the tip of a ray is regenerated after loss, but several specimens show broken and healed rays where no regeneration is visible. Several cases occur of apparent regeneration of a group of rays, as though a large part of one side of the Heliaster had been cut (or bitten) off and the new rays were to replace those so lost; thus in one specimen of *microbrachius*, there are 24 normal rays and 13 much smaller, obviously young rays, side by

side; and in another specimen of the same species there are 25 normal rays and ten young ones side by side.

We are now in position to answer the questions raised by Ritter and Crocker (1900) concerning ray multiplication in Labidiaster and to compare the process in that genus and Heliaster with what takes place in Pycnopodia. The questions may be taken up in the order in which they were asked.

(1.) *Do the new rays come in in distinct generations?* They do not, but develop entirely independently of each other. A considerable number may develop at approximately the same time, often as many as six or seven and sometimes eight or nine in *H. polybrachius*, but they show no definite relation to each other.

(2). *Do the successive rays arise at the same and definite places?* There is much evidence to show that they tend to arise in all four quadrants of the circumference of the starfish about equally, but successively rather than simultaneously. This order is by no means consistently adhered to, however.

(3). *With what number of rays does adult life begin?* In Heliaster there can be little question that the number is five. There is no evidence yet known in the case of Labidiaster.

(4). *Are the new rays disposed bilaterally?* Not as a rule; this point is discussed more fully below.

(5). *Is there a ray corresponding to ray A of Pycnopodia?* Apparently not.

The symmetry of Heliaster, referred to under question four, requires a few words of description. Perfect radial symmetry is of course out of the question, as there is only one stone-canal and madreporite, but leaving those organs and the racemose and rectal glands out of account, approximate radial symmetry is possible in Heliaster, apparently only in the 5-rayed stage; for the interradius, 5–1 rarely develops any accessory rays and never as many as the other interradii. Bilateral symmetry, however, if we except the racemose and rectal glands, is clearly shown by some individuals, but the plane of division is quite different from that which Ritter and Crocker (1900) show is the adult plane in Pycnopodia. For while in Pycnopodia, the madreporite lies always in the second interradius to the left of the posterior half of the line of division, in Heliaster the only possible plane of symmetry is through the madreporite. In Pycnopodia moreover the plane is determined by the position of the accessory rays and every normal individual is bilaterally symmetrical (approximately of course), while in Heliaster the accessory rays have no

definite relation to the plane and only certain, relatively few, individuals reveal the symmetry. Theoretically, of course, any Heliaster with an odd number of rays show this bilaterality but in none of those examined was it shown, except those which had at least 25 rays. In all those with just 25 rays, the plane of symmetry, with 10 accessory rays on each side, is clearly indicated. Above 25, any odd number of rays may be accompanied by bilateral symmetry but it is not commonly, for of the 11 specimens tabulated on page 61, it will be seen that only one, a *helianthus* with 35 rays, can be considered truly symmetrical.

It appears therefore that in Heliaster, the formation of new rays is fundamentally different from that in Pycnopodia. This is well brought out by a comparison of figure 1, plate 8, with Ritter's and Crocker's (1900) figure 1, plate 13. In Heliaster the first three new rays are distributed one each in the three successive interradii to the left of the one in which the madreporite lies, while in Pycnopodia all three (counting A as the first accessory ray) lie in the single interradius 1–2. It is hard to believe that the two methods have anything in common, the ray A is so conspicuous and plays such an important part in Pycnopodia. In Heliaster the first accessory ray probably (?) appears in interradius 1–2, the second in 2–3, and the third in 3–4. Then apparently, as is shown by figure 2, plate 8, a new ray arises in 1–2, another in 2–3, another in 3–4, and then another in 1–2. Later on the process begins in interradius 4–5 and by the time 25 rays are formed, it is going on at about an equal rate in those four interradii. As we have already seen, it is only very exceptionally that the interradius 5–1 takes part in ray formation. It is not unfair to interpret the facts here brought out as showing that the formation of new rays in Heliaster follows this rule: —

The process begins in interradius 1–2, *soon after larval life ends, and goes on rapidly there until two or three accessory rays are formed, the similar activity of interradii* 2–3, 3–4, *and* 4–5 *following in order. At the time the process begins in* 4–5, *the rate of development in* 1–2 *has begun to decrease, and by the time there are* 25 *rays, each of the four interradii has formed five accessory rays, and the rate of development has greatly decreased and become approximately equal in them all. Subsequent formation of new rays follows the same general order, the twenty-sixth ray appearing in interradius* 1–2, *but after* 35 *rays are formed further development is sporadic.*

Of course it is not claimed for a moment that the above statement is a "law" governing ray formation in all Heliasters, as the material examined has been too scanty to determine how generally any such rule is

followed. But it can hardly be questioned that it indicates the usual course and is a natural deduction from the facts already given. The process is almost certainly continually modified by physiological conditions, one of which, at least, after the individual is well grown, is very possibly the amount and rate of calcification in the different interradii. Such unknown factors often cause some striking deviations from the suggested rule, as in the two cases previously mentioned, a *canopus* with 24 rays, where interradius 2–3 has only three accessory rays, while 4–5 has six, and a *polybrachius* with 20 rays, where interradius 2–3 has only two accessory rays and 4–5 has five.

If the above suggested rule is the usual course, we should expect to find that in specimens with from 21 to 30 rays, those with an odd number would predominate, but that in those with from 31–40 rays, there would be less tendency to an odd number, and the chances of odd or even would have been about equal. And such proves to be the case; for of 163 mature specimens having 21–30 rays, 98 or 60 per cent have an odd number, while of 170 specimens with 31–40 rays 86, or almost exactly half, have an even number. It is interesting in this connection to call attention to the fact mentioned on p. 45, that *canopus* has a marked tendency to an even number of rays, although they range from 20 to 27. If *canopus* is omitted, there are 89 out of 136 specimens with 21–30 rays, or 66 per cent which have an odd number. The condition in *canopus* is difficult to account for but it is apparently associated with a peculiar tendency in interradius 2–3 to fall behind in the production of new rays. In all of the six specimens examined with from 20–24 rays, that interradius has a smaller number of rays than 3–4, and in four of the six, it has the smallest number of any of the four interradii. In none of the ten specimens of *canopus* examined does interradius 2–3 have a larger number of rays than 3–4. The cause for this curious condition is obscure and we need make no attempt here to determine it, but it seems clear that it accounts for the tendency to an even number of rays in *canopus*. It may be added that there is no very obvious reason why interradius 5–1 develops no accessory rays, although it is very probable that the presence of the stone-canal and axial organ in that interradius is associated with the cause.

In the light of all the facts here brought out with reference to ray formation in Heliaster, it is, to say the least, unfortunate that Ritter and Crocker (**1900**) should have said (p. 263): — "The inconstancy and irregularity of the phenomena of new ray formation certainly finds no support in what takes place in *Pycnopodia* and, as we have shown,

the process will probably be found to be perfectly definite in *Heliaster* also."

The Relationships of Heliaster.

So obvious are the resemblances between Heliaster and Asterias, that such students of starfishes as Müller and Troschel (**1842**) and Lütken (**1872**) declined to separate them generically and even Gray (**1840** and **1866**) only proposed Heliaster as a subgenus. Dujardin and Hupé (**1862**) and Perrier (**1875**), however, considered the multiradiate forms entitled to füll generic rank, but very closely related to Asterias. Viguier (**1878**), on making a careful study of the skeleton, reached the conclusion that Heliaster is not only generically different from Asterias but that it actually is entitled to rank as a family, distinct from the Asteriidae, which he called the Heliasteridae. Since the publication of his paper, Viguier's opinion has been almost uniformly adopted and the Heliasteridae has been accepted as a natural family. The examination of the large amount of material accessible to me has led me to feel that the question needs to be reopened and the evidence re-examined.

Viguier gave six characters upon which the family Heliasteridae is based and we will consider them in the order in which he presents them.

1. *The large number of rays, even more than in Pycnopodia.* This is an obvious and useful characteristic, but as Labidiaster has full as many rays as those Heliasters which have the largest number; as Pycnopodia scarcely falls short of the Heliasters which have the smallest number; and as there is as great a difference between *H. polybrachius* and *H. kubiniji*, as there is between the latter and *Coscinasterias calamaria* (Gray), it does not seem as though much stress could be laid on this point.

2. *The extended coalescence of the rays.* This is also an obvious character but it is not wholly confined to this genus for in some Asterids such as *Asterias ochracea* Brandt (Plate **6**, fig. 3) the fusion of the rays is quite as great as in some Heliasters. Thus a specimen of *A. ochracea* with R = 100 mm. has only 71 mm. free which is practically the same proportion as in some specimens of *H. multiradiatus*. Clearly this character is not altogether distinctive.

3. *The separation of the rays by very strong, true interbrachial walls.* This is probably the best character of which Viguier speaks, for such starfishes with numerous rays as Labidiaster and Pycnopodia, have no true interbrachial walls. It should be pointed out however that the

beginnings of just such walls as occur in Heliaster are to be seen in *Coscinasterias calamaria* (Gray) (Plate 6, fig. 2) and they are well developed in *Asterias ochracea* Brandt (Plate 6, fig. 3). Consequently too much importance must not be attached to this feature.

4. *The position of the mouth at the bottom of a sort of funnel.* The value of this character is an open question but there is no reason for supposing it has any great significance as a structural feature. It is nearly or quite wanting in many individuals, although the best preserved specimens show it more or less clearly. Even if it were always present in normal living individuals, it could hardly be considered of sufficient importance to be a family character.

5. *The fragmentation of the madreporite.* Although the madreporite of an adult *H. helianthus* is usually fragmented, and although the same is true of the other forms with more than 30 rays, yet in young specimens of these species and in adults of *kubiniji* and *multiradiatus* such is not the case, but the madreporite is, on the contrary, exactly as it is in Asterias, simple and convex. The condition of the madreporite cannot then be used even as a generic character.

6. *The peculiar and remarkable form of the odontophore.* In regard to this point, there is room for difference of opinion, for while no one questions the interesting fact which Viguier emphasizes that the basal interbrachial plate (or "odontophore" as he calls it) is fused in Heliaster with a larger interbrachial plate behind it, it is difficult to determine how much value such a character has from a taxonomic point of view. Sladen (1889) holds that it has little or no value and that greater differences in this plate may occur between closely allied species than between other species of quite different genera, so much depends on the number of rays and the character of the adambulacral plates. Careful comparative study of the actinal skeleton of Asterias and Heliaster leads me to believe that Sladen is quite right and that we cannot place any exceptional weight on peculiarities in this so-called "odontophore."

The characteristic features of the family Heliasteridae, then, as given by Viguier, do not seem to bear close examination, and fail to prove of sufficient constancy and distinctiveness to warrant the separation of the genus Heliaster from the Asteriidae. Before the matter is considered settled, however, there are other points to be examined which will throw some light on the subject. It is remarkable that Viguier fails to mention the conspicuous discobrachial wall of Heliaster (Plate 6, fig. 1), for there is no other feature of the anatomy which is so characteristic of the genus. It is quite possible that, with the small amount of material

at his disposal, he did not feel justified in mutilating a specimen to such an extent as to expose this wall sufficiently to make him realize its unique character. It shuts the cavity of each ray off from the cavity of the disc completely, the only communication between the two being a small foramen through which the duct of the digestive gland passes. I have found no trace of any such wall in any other starfish which I have examined, and, although further investigation may show that it is not unique, it is undoubtedly the most striking feature of the internal anatomy of Heliaster. It is easy, however, to see how such a wall might have developed, for, with the coalescence of the rays and the consequent doubling of the interbrachial walls, it would be natural that a stronger union between the rays and disc should arise by the expansion of the proximal ends of those walls. The subsequent increase and coalescence of such expansions would readily follow, thus giving a very unusual, but necessary, strength to what would otherwise be a line of weakness. — The further examination of the internal anatomy of Heliaster reveals some interesting similarities with Asterias, which have not been noted hitherto. The reproductive organs occupy the same position as in that genus, and are identical in form, so that the only difference is in the actual number of gonads, there being a pair in each ray in both genera. The form and position of the stone-canal and the axial organ are identical in the two. The racemose glands (Tiedemann's bodies) are similar in form and position, but are much more numerous in Heliaster than in Asterias, ranging from 10 to 26 in the twelve specimens of *kubiniji* and *polybrachius* examined. They do not show any regularity in position, however, or any correlation between their number and the size of the individual, or the number of rays. The digestive system of Heliaster (Plate **7**, fig. 1) is surprisingly like that of Asterias in spite of the separation of the disc cavity from the rays. The stomach is very capacious, and is obviously pushed out of the mouth in feeding, just as in Asterias, and (as already mentioned on p. 59) its five pouches are each attached by a pair of strong muscles, as in that genus, to the ambulacral plates of the basal part of a ray. These muscles pass from the stomach through the openings in the discobrachial wall (which are perhaps a trifle larger in these rays) used by the ducts of the digestive glands. This pentamerous symmetry of the stomach-muscles is most striking, and it can hardly be doubted that it reveals a close relationship to Asterias. The intestine is short, and bears the customary rectal gland, which consists, as in Asterias, of several much divided branches.

Turning now to the external features of Heliaster, we find, as is well known, that the abactinal skeleton, the papulae, the pedicellariae, and the armature of the adambulacral plates are essentially the same as in Asterias. It has commonly been stated also that the two genera are alike in the quadriserial arrangement of the pedicels. As a matter of fact, however, the real arrangement of the pedicels in Heliaster is quite different from what is found in Asterias, for while a quadriserial arrangement does occur in some species of Heliaster, it is virtually confined to the middle portion of the ray, while in other species it is hardly correct to speak of a quadriserial arrangement at all. These various conditions are shown on Plate **7** from which it will be seen that although in the middle of the ray there is a distinctly quadriserial arrangement in *microbrachius* (Fig. 11), in *kubiniji* (Fig. 9) that is scarcely the case. At the base of the ray the arrangement is unqualifiedly biserial in all the species (Fig. 10), at least for the first ten or twelve pairs of pedicels. In young individuals (Fig 12), the biserial arrangement is marked even at the middle of the ray. This condition is certainly perplexing if Heliaster is merely an Asterias with numerous rays, for if that were the case, the species with the fewest rays (*kubiniji*) ought to show most clearly the quadriserial arrangement, while a young individual with only 17 rays certainly ought to have the same arrangement well marked. As we have just seen, the reverse is the case. However, it seems probable that increase in the number of rays, in a species having four rows of pedicels, with the consequent lateral crowding, would lead to radial extension, which would result in the quadriserial arrangement gradually becoming irregularly, and finally perfectly, biserial, as we find it at the base of the rays in Heliaster. That such a result does follow an increase in the number of rays in a species with the quadriserial arrangement of the pedicels, is shown by *Coscinasterias calamaria* (Gray) (Fig. 13), where the first two or three pairs of pedicels of each ray are arranged in a single series on each side. If, however, we are to assume that the change here first indicated in Coscinasterias is continued in Heliaster to a far greater extent, we shall have to admit that it is carried to different degrees of completeness in the different species. It seems to have gone further in the species with the narrower, freer, and more cylindrical rays, where the quadriserial arrangement is nearly obliterated, than in those with broader and flatter rays, where the pedicels still appear to be in four series at the middle of the ray. Apparently, after there are 15–20 rays, the change to a biserial arrangement of the pedicels is not promoted so much by the number or degree of coalescence of the rays, as by their form and width.

From this brief summary of the more obvious anatomical features of Heliaster it is clear that the relationship with Asterias is very close, the only important differences being in the number of rays, the degree of their coalescence and the resulting modification of the actinal skeleton and arrangement of pedicels. It will of course be a matter of opinion whether these differences warrant the maintenance of the family Heliasteridae. It seems as though such a course emphasized too strongly the differences between Asterias and Heliaster and tended to conceal their much more important resemblances, and while the Heliasters might be considered a sub-family (Heliasterinae) of the Asteriidae, it would be unwise to isolate them further. If this sub-family be recognized, it is possible that the two Heliasters with relatively few, long, free rays (*multiradiatus* and *kubiniji*) could be separated generically from the others. It is difficult to do this, however, on account of the intermediate characters shown by *canopus*, which has few, rather long, and quite free rays, but whose natural relationship is obviously with *helianthus*. Should we make a second genus of these two species, leaving *cumingii*, *polybrachius*, and *microbrachius* for a third, we should doubtless have a natural grouping of the species, but the definition of these "genera" would tax the keenest specialist, and it is difficult to see any real advantage from such a division. It is, moreover, quite possible that when these starfishes are studied as living organisms (instead of as museum specimens), and from a more extensive series of localities, our idea of their interrelationships may be considerably changed.

Granting, then, that Heliaster is to be accepted as a genus of Asteriidae, we may well inquire as to its relation to other genera of that family, and we naturally turn to Pycnopodia as a probable near-ally, on account of the large number of rays. That Heliaster is allied to Pycnopodia has recently been both assumed and affirmed by Ritter and Crocker (**1900**). They make the following statement in a footnote on page 249: — "There appears to be general agreement among authorities that *Pycnopodia* and *Heliaster* are rather more closely related than are *Heliaster* and *Labidiaster*. A. Agassiz, '**77**; Perrier, '**93**; Ludwig, '**97**; Studer, '**84**; Vignier, '**78**, etc." (both in this place and on p. 270, Viguier's name is misspelled, by a common typographical substitution). As my own investigations had led me to a different conclusion, I looked up the references here given, making use of course of Ritter's and Crocker's bibliography, with the following remarkable result: —

A. Agassiz, '77.

North American Starfishes. Mem. M. C. Z., **5**, No. 1.

No mention is made of either Heliaster or Labidiaster, nor can I find the slightest hint of the writer's opinion on the position of either genus. I may add further that Mr. Agassiz assures me that he has never expressed or held any such opinion as is here ascribed to him.

Perrier, '93.

Traité de Zoologie. Première partie. Paris, 1893.

The author makes no direct reference to the question, but the position he assigns to Heliaster might not unfairly be interpreted as showing that he holds the view ascribed to him.

Ludwig, '97.

Die Seesterne des Mittelmeeres.

I have been able to find no reference whatever to any one of the three genera concerned, though I have very carefully and repeatedly examined this splendid monograph.

Studer, '84.

Abh. d. k. Akad. d. Wiss. zu Berlin, p. 1–64.

No reference whatever is made to either Heliaster or Pycnopodia.

Viguier, '78.

Arch. de Zool. exp. et gen., **7**, p. 33–250.

Although the author does not make any positive statement as to the relationship of Pycnopodia and Heliaster, it is clear from his remarks on page 116 that he does not consider them closely allied, while the statements on pages 118–119 indicate that he does consider Heliaster as intermediate between the Asteriidae and Brisingidae (to which family Labidiaster is commonly assigned), while Labidiaster, he thinks, may be intermediate between Heliaster and Brisinga.

It is clear, therefore, that the only "general agreement" which these five authors show is in avoiding the expression of any such opinion as is ascribed to them. It is very difficult to understand why Ritter and Crocker should have given these references at all, for they certainly do not support their contention, even indirectly.

On comparing specimens of the three genera concerned it will be seen that superficially they are somewhat similar, but that the more numerous rays and the larger disc ally Labidiaster and Heliaster more closely to each other than to Pycnopodia, although the stout abactinal skeleton of Heliaster separates it from both. The ambulacra in Pycnopodia are moreover very broad, and the pedicels are distinctly quadriserial almost to the actinostome, while in Heliaster the ambulacra are nar-

rower and the pedicels distinctly biserial at the base of the ray, as they are in Labidiaster throughout; the general appearance of the ambulacra in Heliaster is thus more like Labidiaster than it is like Pycnopodia. The buccal membrane and the mouth parts are essentially alike in all three genera, while the adambulacral armature shows no close similarity between either two. The pedicellariae are alike in all three, but those of Heliaster (Plate 7, figs. 2–5), while somewhat more like those of Pycnopodia in form, are distributed more as in Labidiaster. The digestive system of the latter is more like that of Pycnopodia than it is like that of Heliaster; at least the material available to me shows no indication of the five pairs of stomach-muscles, so characteristic of Asterias and of Heliaster, in either Pycnopodia or Labidiaster, nor can I find any reference to them in the published descriptions of either genus. In the number of racemose glands, Heliaster and Labidiaster are alike, having a large number (usually more than 15, often more than 20) without definite arrangement, while Pycnopodia, according to Ritter and Crocker, has only 9 or 10, and these are definitely located. The discobrachial wall of Heliaster is wanting in both the other genera, and even their interbrachial walls are reduced to mere sheets of connective tissue with little or no calcification. Were the case to rest here we should still be somewhat in doubt as to whether Heliaster or Pycnopodia were the nearer to Labidiaster, but there could be little question that Heliaster is nearer to the latter than it is to Pycnopodia. There is, however, another and very important point to be considered, and that is the location and sequence of new rays, which, as we have already seen, is apparently alike in Heliaster and Labidiaster, and places them in striking contrast to Pycnopodia. This feature alone is sufficient to completely separate the last from the others, and Viguier's opinion that Heliaster is intermediate between Asterias and Labidiaster seems therefore to be justified by these more recently discovered facts. Whether the latter is intermediate between Heliaster and the Brisingidae is somewhat less certain. The geographical connection between Heliaster and Labidiaster is obvious, since the latter replaces the former on the southern coasts of South America, but the remainder of the Brisingidae are, for the most part, widely separated geographically from Labidiaster, and there is reason to believe that they have originated from the Asteriidae quite independently of that genus. On the whole, it looks as though Labidiaster had originated as an offshoot from Heliaster, living in colder and deeper water, while Odinia, and perhaps Brisinga, too, are probably similarly related to the genus Asterias.

The Interrelationships of the Species, and the Factors which have aided their Development.

There are few starfishes whose habitat is so exclusively littoral as that of Heliaster, and there are not many genera, containing several species, whose area of distribution is so circumscribed. For these reasons the genus offers an unusual opportunity for the study of the influence of environment and the effect of isolation. Although this study could only be properly carried on in the regions where the Heliasters live, nevertheless the examination of a large number of specimens suggests certain conclusions which are worth noting. In the first place we see there are four areas, which so far as our present knowledge goes, are distinctly separated from each other, where Heliaster occurs, namely: — West Coast of Mexico and Central America; West Coast of South America from Ecuador to Chili, inclusive; Galapagos Islands; Juan Fernandez. In each of the first three regions two species of Heliaster occur, and in the fourth, one, but there is no species common to any two of the districts. We have no means of knowing which species is nearest the ancestral form, but it seems almost certain that the species with the fewest and least united rays are the most primitive. We are equally ignorant as to the place of origin of Heliaster, but there can hardly be any question that it was somewhere along the mainland coast. If these two points are assumed, *kubiniji* must be the nearest to the original Heliaster. We can see that as there are no nearly allied species on the western tropical coasts of America to compete with it, this form might gradually spread southward, while it would not be likely to extend north of Lower California, as it would then come into compétition with numerous other Asteriidæ. Whether Heliasters still occur on the coast of Colombia we do not know, but whether they do or not is of no special importance in this connection, for *kubiniji* does not range very far south of Mexico and is therefore entirely isolated at present from its South American relatives. These latter under the different environmental conditions south of the equator seem to have developed a larger number of rays and to have them more fully united, as we find in *helianthus*. By a continued (though slight) increase in the number of rays, and a marked increase in their coalescence, accompanied by the development of stouter, capitate, abactinal spines, *polybrachius* has arisen. The origin of *microbrachius* is less clear, but its affinities with *polybrachius* are so much more apparent than any with *kubiniji*, we are almost forced to believe that it represents a return northward of short-rayed Heliasters, which owing to

their obvious differences have not been in real competition with *kubiniji*, and which in the environment north of the equator, new to them, have developed the numerous, slender abactinal spines which distinguish them from their southern ally. The fact that *microbrachius* occurs at Panama and Pearl Island may be interpreted to support this hypothesis. The relationships of the island forms are obvious, for *multiradiatus* is very closely allied to *kubiniji*, *cumingii* is quite as close to *polybrachius* and *canopus* is almost certainly an offshoot from *helianthus*. — These relationships, both phylogenetic and geographical, may be indicated by such a sketch as Diagram 6, it being understood that the relative length of the lines has no significance whatever.

Because of the extremely littoral habits of Heliaster, there can be no question that the island forms have reached their present homes as larvae transported by ocean currents. Owing to the distances however and the slow rate of travel, the chance of survival is very small, and it must be seldom indeed that young Heliasters from the mainland ever reach the Galapagos or even Juan Fernandez. The latter islands seem to have been reached as yet only by the single species (*helianthus*) from the nearest mainland, which under the stress of new conditions has become changed so that it breeds earlier in life, and is consequently much smaller than its parent form, and has more delicate spines, and fewer, freer rays. The Galapagos have been reached by young *polybrachius* from South America and also by young *kubiniji* from Mexico, but if we may judge by the relative amount of change, Juan Fernandez was populated by Heliaster long before the Galapagos. At the latter islands, *cumingii* appears to be much more abundant than *multiradiatus*, so we are justified in thinking *polybrachius* was the first comer, but both are so recent, the changes are as yet slight.

Of the factors which have led to this development of diverse forms of Heliaster, one at least stands out so clearly that there can be little doubt of its importance, and that is *isolation*. Were only the mainland species known, this factor would not be so obvious, though it would be suggested by the apparent lack of Heliasters on the coast of Colombia. But when we consider the two Galapagos species, and particularly when we study *canopus*, it is hard to doubt that the complete isolation of these small groups of individuals has been of great importance in the formation of the new species. In the case of *canopus*, there has been sufficient time, so that the species is sharply distinct, while the Galapagos species seem to be as yet only imperfectly defined. It is not necessary to claim that isolation has been the only, or even the essential, factor. Indeed the

probable existence of connecting links between *cumingii* and *polybrachius* at the Galapagos makes it very unlikely that it is merely the environment and isolation which are at work there. It seems clear that natural selection has been an important agent in the case of *canopus* at any rate,

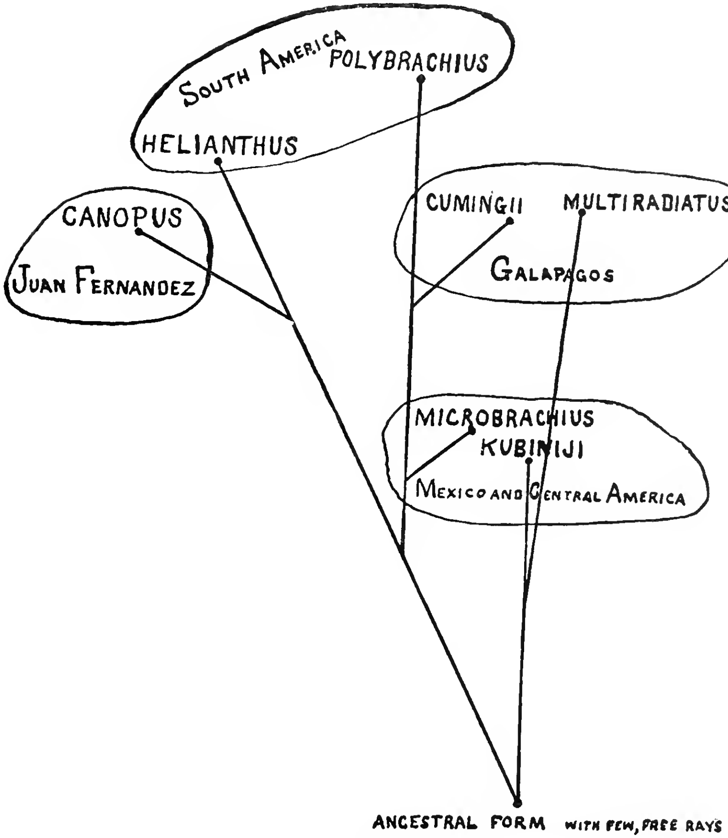


DIAGRAM 6.

To show the phylogenetic and geographical relationships of the species of Heliaster.

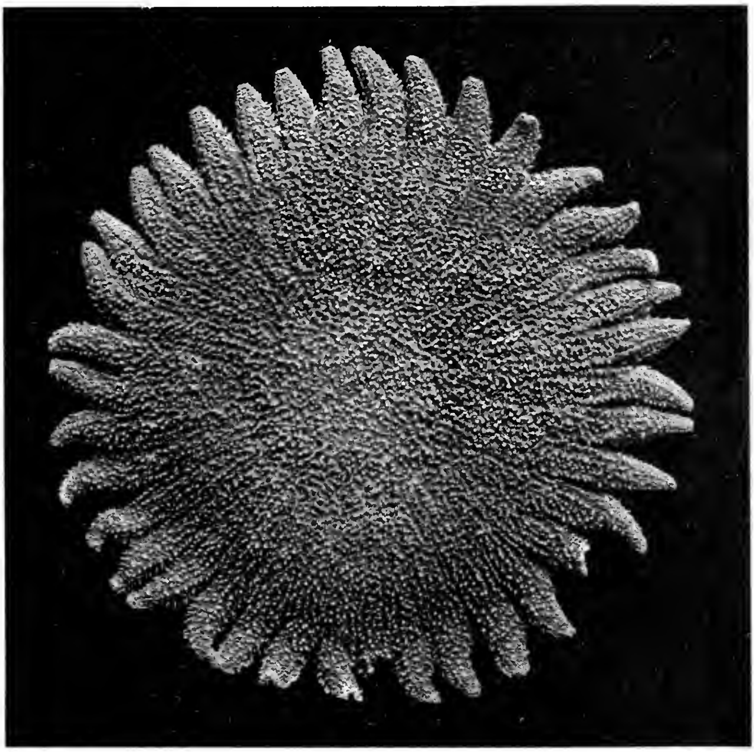
for while it can be claimed, if they please, by those, who are "done with meekly accepting the dictum . . . that when we understand *all* the conditions of the life of an organism, then and only then are we entitled to say of this or that character that it is not of life or death value,"[1]

[1] Kellogg, V. L., Science, Nov. 16, 1906, p. 627.

that the number of rays, the amount of their fusion, and the size and arrangement of the abactinal spines are characters of no value in the struggle for existence, there can hardly be any question that the ability to reproduce vigorous young, at an early period of life, would be a factor of importance in the establishment of Heliaster on an isolated island. As diminutive size, a small number of rays and their comparative freedom, and slender abactinal spines are youthful characters in Heliaster, it is significant that we find them correlated in *canopus* with sexual maturity. It can hardly be doubted that natural selection, aided by isolation and the correlation of characters, has, by working on an inherently variable and plastic organism, been the cause of the evolution of *canopus*, and I see no reason to question the probability that a similar process is going on in the formation of two new species of Heliaster at the Galapagos.

PLATE 1.

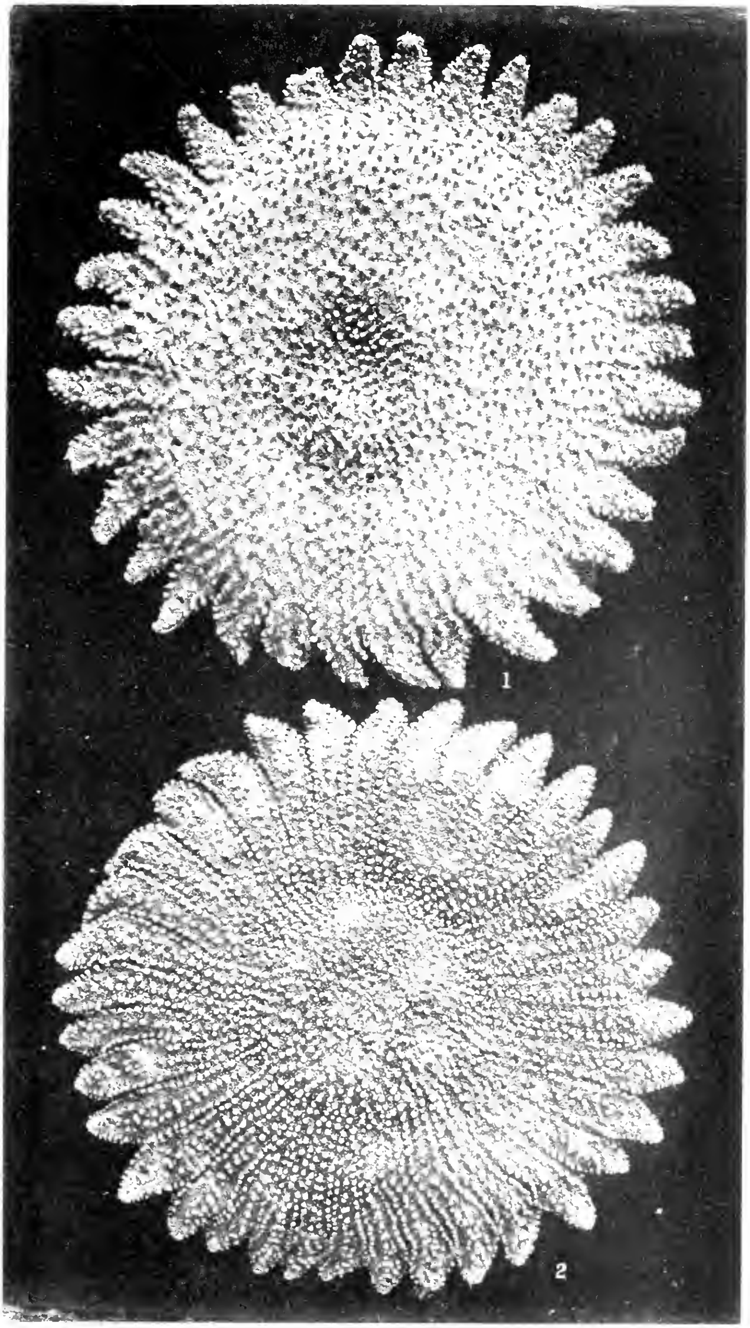
Heliaster microbrachius Xantus. Abactinal surface. $\times \frac{7}{10}$.



HELIOTYPE CO., BOSTON.

PLATE 2.

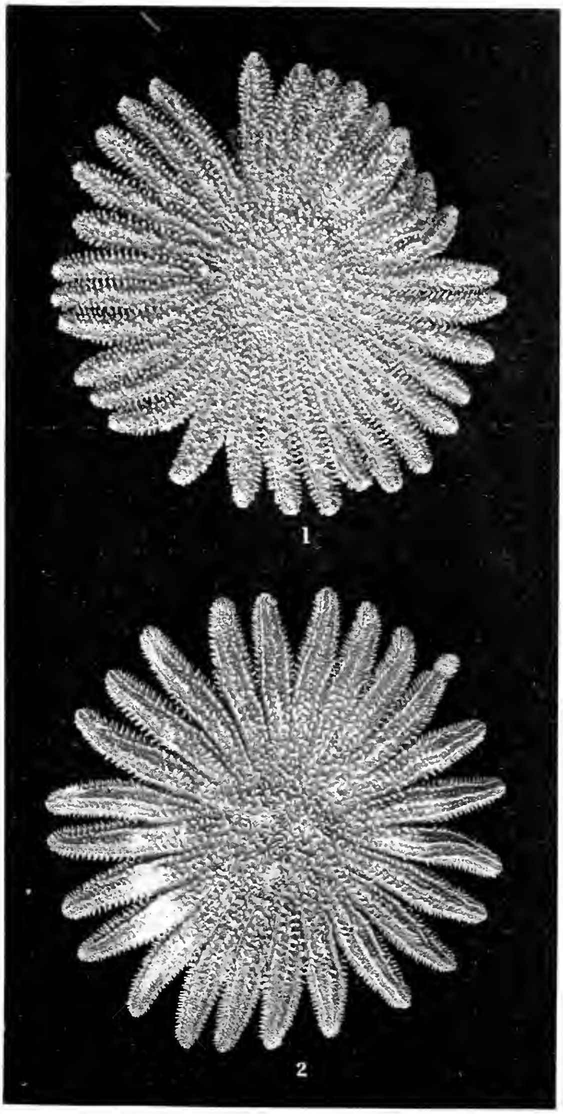
Fig. 1. Heliaster cumingii (Gray). Abactinal surface. $\times \frac{7}{10}$.
Fig. 2. „ polybrachius, sp. nov. „ „ $\times \frac{7}{10}$.



HELIOTYPE CO., BOSTON.

PLATE 3.

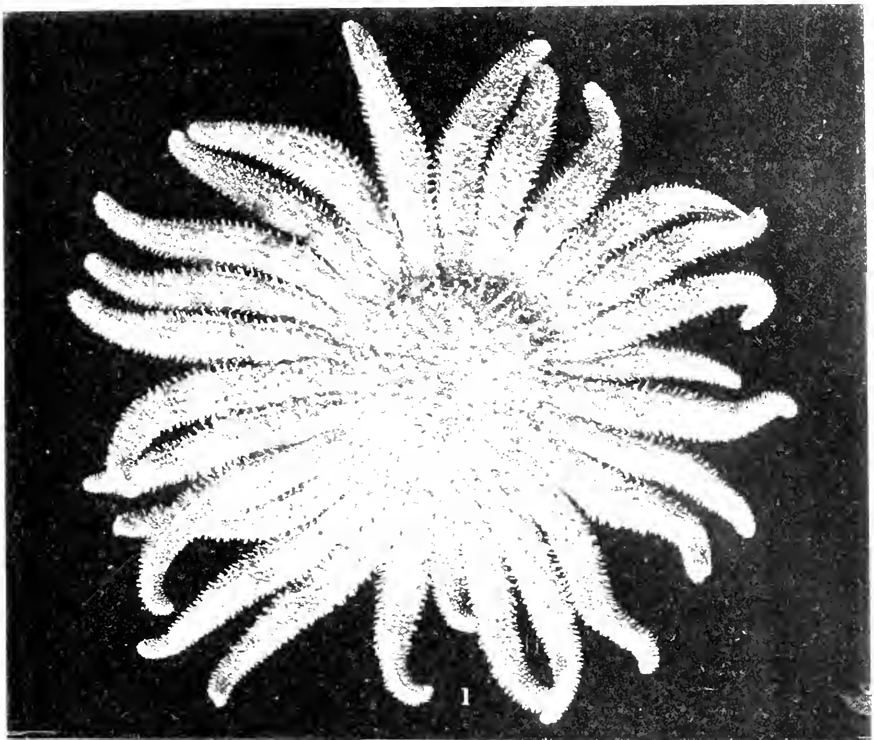
Fig. 1.	Heliaster helianthus (Lamarck), juv.	Abactinal surface.		$\times \frac{7}{10}$.
Fig. 2.	„ canopus Perrier, adult.	„	„	$\times \frac{7}{10}$.



HELIOTYPE CO., BOSTON.

PLATE 4.

Fig. 1.	Heliaster	multiradiatus (Gray).	Abactinal	surface.	$\times \frac{7}{10}$.
Fig. 2.	„	kubiniji Xantus.	„	„	$\times \frac{7}{10}$.



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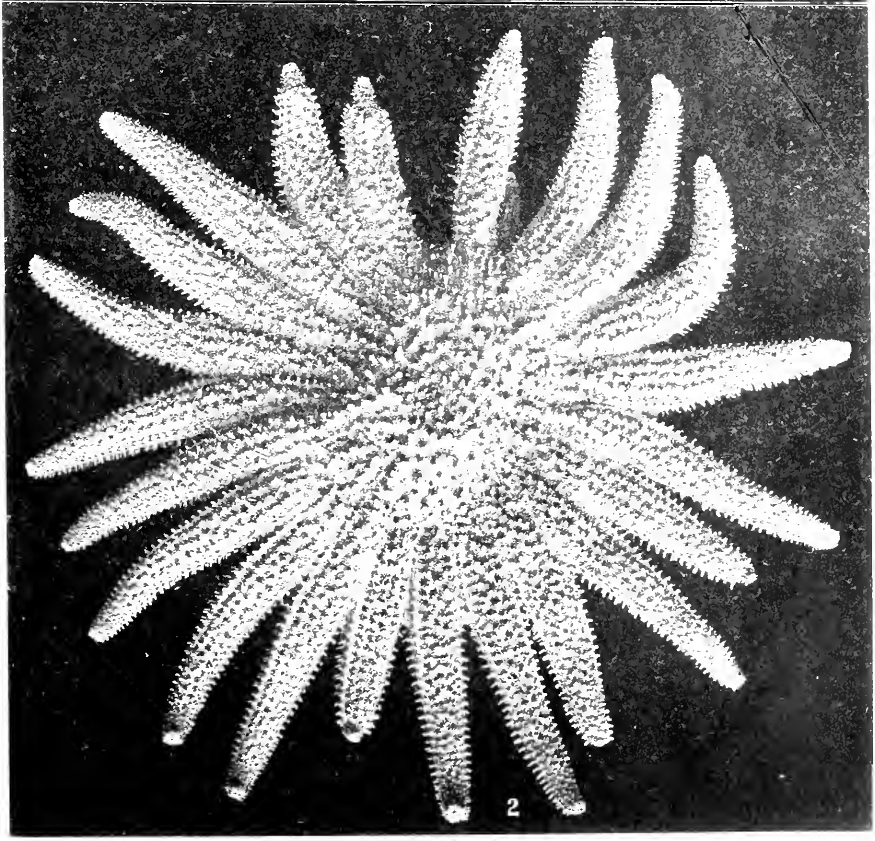

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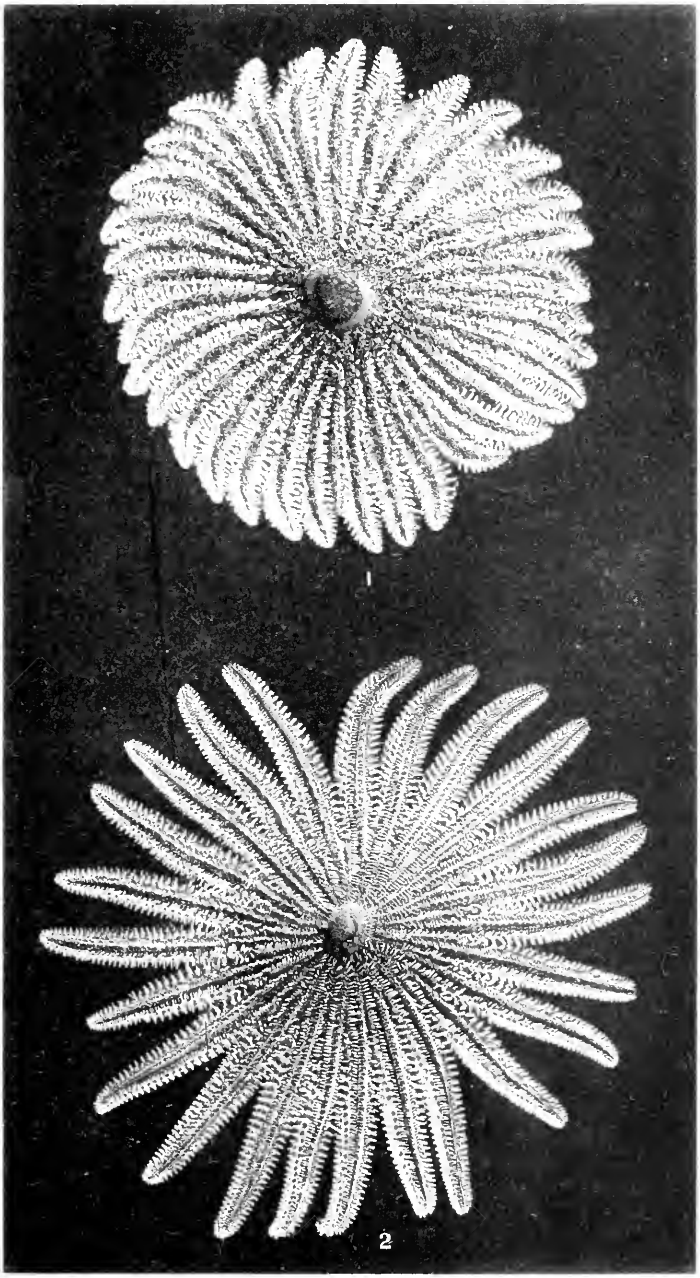
PLATE 5.

Fig. 1. Heliaster cumingii (Gray). Actinal surface. $\times \frac{7}{10}$.
Fig. 2. „ „ kubiniji Xantus. „ „ $\times \frac{7}{10}$.



HELIOTYPE CO., BOSTON.

PLATE 6.

Fig. 1. Heliaster kubiniji Xantus. Abactinal surface and all inner organs removed, to show the interbrachial and discobrachial walls. $\times \frac{7}{10}$.

Fig. 2. Coscinasterias calamaria (Gray). Abactinal surface and all inner organs removed, to show the incipient interbrachial walls. $\times \frac{7}{10}$.

Fig. 3. Asterias ochracea Brandt. Abactinal surface and all inner organs removed, to show the coalescence of the rays and the interbrachial walls. $\times \frac{7}{10}$.

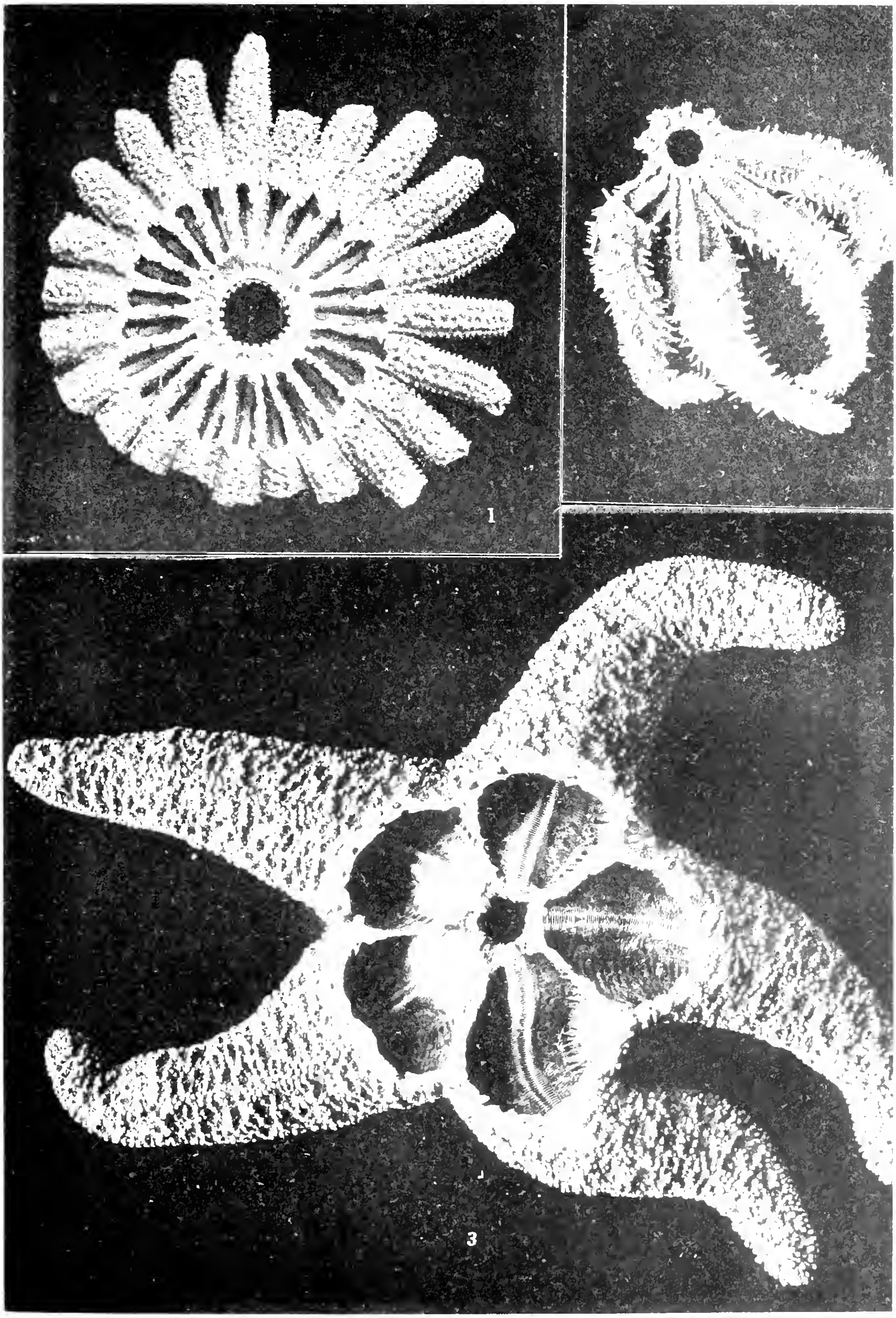

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PLATE 7.

Figs. 1–7. Heliaster helianthus (Lamarck).

1. Digestive system, including the intestine (*IN*) with its rectal gland, the stomach with "blood-vessels" (?) (*BV*) on its abactinal surface, the bases of the digestive glands of three rays, the ducts of the other rays, and the paired stomach-muscles of the five primary rays. The stone-canal (*SC*) may be seen between rays I and V. Nat. size.
2. A large forficiform pedicellaria. × 70.
3. A small " " × 70.
4. A forcipiform pedicellaria, from one edge. × 70.
5. A similar " " " side. × 70.
6. The madreporite of a large adult. × 2.
7. " " " " well-grown young individual, 95 mm. in diameter. × 2.

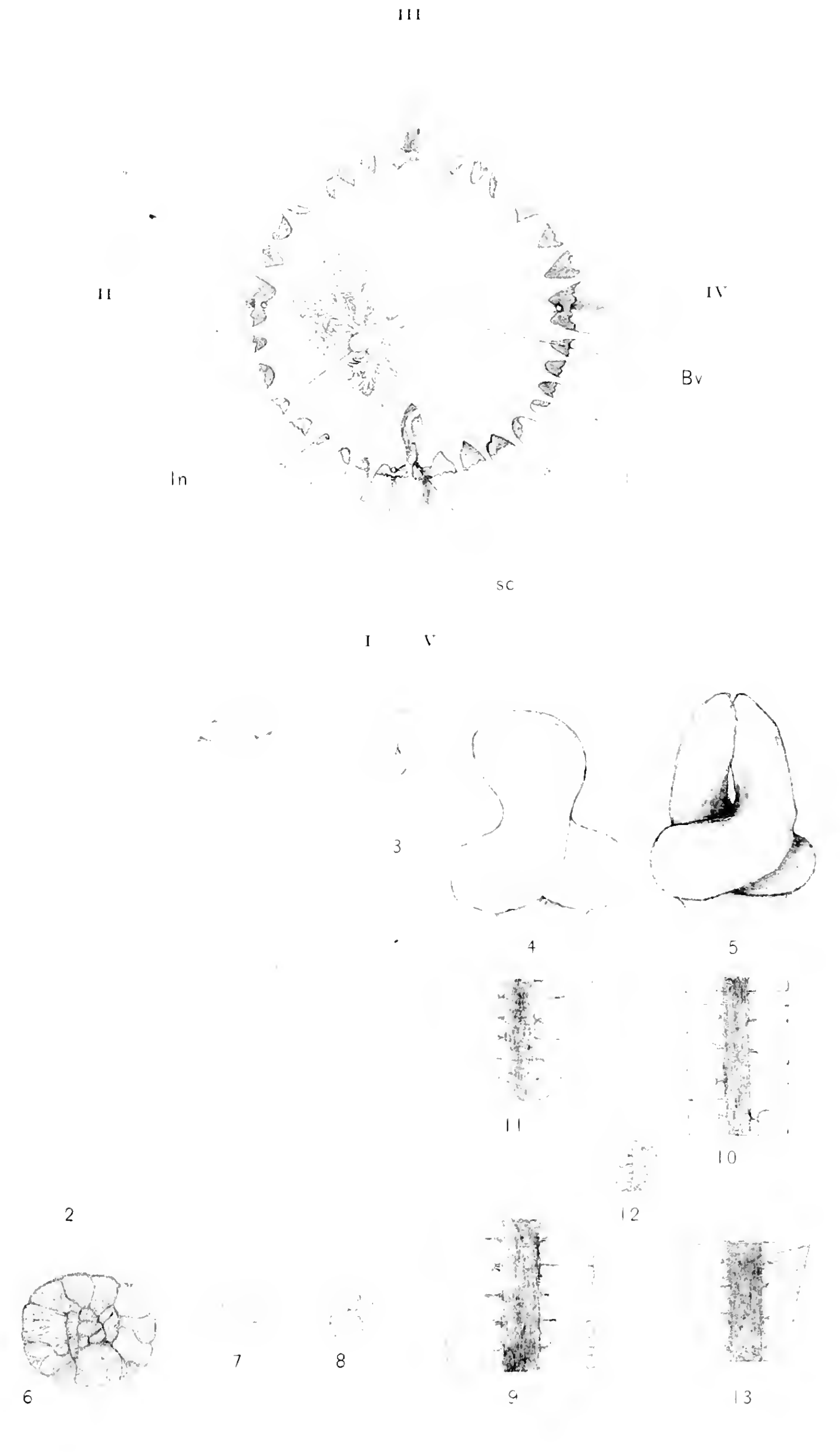
Figs. 8–10. Heliaster kubiniji Xantus.

8. The madreporite of an adult. × 2.
9. Ambulacral plates from near middle of ray, seen from the outside, to show the scarcely quadriserial arrangement of the pedicels. × 5.
10. Ambulacral plates from near peristome, seen from the outside, to show the biserial arrangement of the pedicels. × 5.

Fig. 11. Heliaster microbrachius Xantus. Ambulacral plates from near middle of ray, seen from the outside, to show the quadriserial arrangement of the pedicels. × 5.

Fig. 12. Heliaster polybrachius, sp. nov. Very young individual, only 40 mm. in diameter. Ambulacral plates from near middle of ray, seen from the outside, to show the biserial arrangement of the pedicels. × 5.

Fig. 13. Coscinasterias calamaria (Gray). Ambulacral plates from near peristome, seen from the outside, to show the biserial arrangement of the pedicels. × 5.



HELIOTYPE CO., BOSTON

PLATE 8.

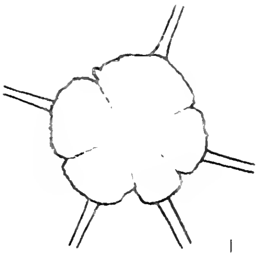
Diagrams to show the relative position of the five primary rays in Heliaster, and the increasingly numerous accessory rays. The heavy line indicates the outline of the stomach with its five pairs of muscles, which determine the primary rays.

Figs. 1–6. Heliaster kubiniji Xantus.

1. An 8-rayed individual.
2. A 12-rayed ,,
3. A 15-rayed ,,
4. A 21-rayed ,,
5. A 23-rayed ,,
6. A 25-rayed ,, (Note the remarkable symmetry at this stage).

Fig. 7. Heliaster canopus Perrier. An exceptional 27-rayed individual.

Fig. 8. Heliaster polybrachius, sp. nov. A large 37-rayed individual.



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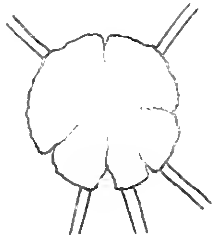

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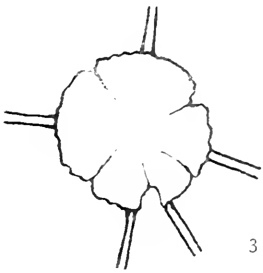

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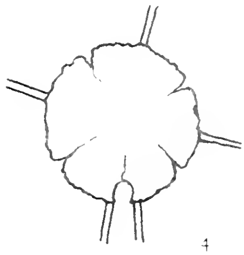

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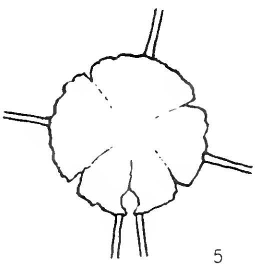

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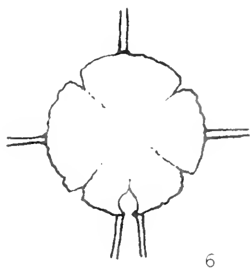

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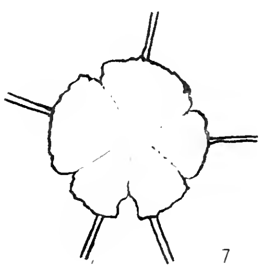

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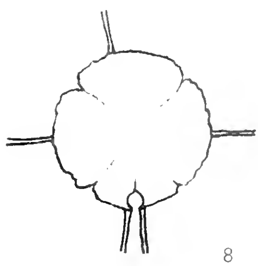

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HELIOTYPE CO., BOSTON.

Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. LI. No. 3.

TYPES OF FOSSIL CETACEANS IN THE MUSEUM OF COMPARATIVE ZOÖLOGY.

By C. R. Eastman.

With Four Plates.

CAMBRIDGE, MASS., U.S.A.:

PRINTED FOR THE MUSEUM.

June, 1907.

No. 3 — *Types of Fossil Cetaceans in the Museum of Comparative Zoölogy.* By C. R. Eastman.

There are preserved in the Museum of Comparative Zoölogy, besides other interesting Cetacean remains, the types and only known representatives of three species of Odontocetes from the middle and late Tertiary formations of this country. Two of these exemplars belong to the Delphinoid, and the other to the Ziphioid division of toothed whales. One of the Delphinoid types has served for the establishment of a distinct genus, Lophocetus, whose characters have been insufficiently described, and precise systematic relations are admitted to be uncertain. The original has never been satisfactorily figured, and its companion Delphinoid type, the so-called *Delphinus occiduus* of Leidy, has not been illustrated at all. The present Bulletin is devoted principally to a consideration of these two Delphinoids.

LOPHOCETUS Cope.

Proc. Acad. Nat. Sci. Phil., 1867, p. 146.

First described by Harlan in 1842 under the name of *Delphinus calvertensis*, the species was made by Cope the type of Lophocetus, and placed in the vicinity of Inia and Pontoporia (= Stenodelphis). In fact, it was held to be distinguished from the former of these genera only by the " cylindric form of the posterior alveolae, which renders it probable that the teeth were not furnished with lobes as in Inia." More than a score of years later, in 1890, the same author speaks with less assurance concerning its relations: " Its position is uncertain; the skull resembles that of Inia, but the roots of the teeth are cylindric. The temporal and occipital ridges are very strong. Skeleton unknown."[1]

Save for one or two exceptions, subsequent writers have accepted Cope's general determination. Dr. Theodore Gill, in 1872, recognized Inia and Platanista as types of independent families, and provisionally placed Lophocetus among fossil Iniidae.[2] The more usual practice has been to assign subfamily values to the groups represented by the two modern genera, and include them under Flower's comprehensive designation of Platanistids. Dr. O. P. Hay accordingly refers Lophocetus, though with some reservation, to the subfamily Platanistinae.[3] On the other hand Dr. E. C. Case states positively that its position is with the Iniinae

[1] The Cetacea. Amer. Nat., 1890, **24**, p. 606.

[2] Arrangement of the families of Mammals. Smithson. Misc. Coll., No. 247.

[3] Fossil Vertebrata of North America. Bull. 179, U. S. Geol. Surv., 1902, p. 590.

among "forms with cylindrically rooted teeth." [1] The only author who has argued against an association with Platanistids, as commonly understood, is Prof. J. F. Brandt, who concluded from the general aspect of the skull and form of the teeth that it approached very closely the existing Whitefish, *Delphinapterus leucas.* He even questioned the propriety of regarding it as the type of a distinct genus: "Der Schädel ähnelt offenbar dem von *Delphinapterus leucas.* Als Typus einer eigenen Gattung möchte ich sie daher, wenigstens vorläufig, noch nicht gelten lassen." [2] Within recent years Dr. Othenio Abel has reiterated the same opinion.[3] Thus the matter stands at the present time.

It may be well to present here Cope's original definition of the genus, to which nothing has since been added. This is given as follows:

LOPHOCETUS Cope.

"Temporal fossa truncated by a horizontal crest above, prolonged backwards and bounded by a projecting crest, which renders the occipital plane concave. The same crest prolonged upwards and thickened, each not meeting that of the opposite side, but continued on the inner margins of the maxillary bones, turning outwards and ceasing opposite the nares. Front, therefore, deeply grooved. Premaxillaries separated by a deep groove. Teeth with cylindric roots."

Lophocetus calvertensis (Harlan).

1842. *Delphinus calvertensis* Harlan, Bull. of Proc. Nat. Inst., p. 195, Plates, **1–3**.
1842. *Delphinus calvertensis* Dekay, Nat. Hist. N.Y. Zool. pt. 1, p. 136.
1842. *Delphinus calvertensis* Markoe, L'Institut, **10**, p. 384.
1866. *Pontoporia calvertensis* Cope, Proc. Acad. Nat. Sci. Phil., p. 297.
1867. *Lophocetus calvertensis* Cope, Proc. Acad. Nat. Sci. Phil., p. 144, 146.
1869. *Lophocetus calvertensis* Leidy, Journ. Acad. Nat. Sci. Phil., (2) **7**, p. 435.
1873. *Lophocetus calvertensis* Brandt, Mém. Acad. Imp. Sci. St. Petersb., (7) **20**, p. 288.
1880. *Lophocetus calvertensis* Van Beneden and Gervais, Ostéographie des Cètacés, p. 512.
1890. *Lophocetus calvertensis* Cope, Amer. Nat., **24**, p. 606, 615.
1896. *Lophocetus calvertensis* Roger, Verzeichniss fossiler Säugethiere, p. 79.
1899. *Lophocetus calvertensis* Abel, Denkschr. k.k. Akad. Wissench., **68**, p. 869, 873.
1902. *Lophocetus calvertensis* Hay, Bull. 179, U. S. Geol. Surv., p. 590.
1904. *Lophocetus calvertensis* Case, Maryland Geol. Surv. Miocene, **26**, p. 9, Plates 16, Fig. 1.

The type specimen consists of a well-preserved skull, from which the lower jaw and forward extremity of the muzzle are wanting. There are preserved besides all of

[1] Maryland Geological Survey, Miocene, 1904, p. 9.

[2] Die fossilen und subfossilen Cetaceen Europa's. Mém. Acad. Imp. Sci. St. Petersb., (7) 1873, **20**, p. 288.

[3] Fossile Platanistiden des Wiener Beckens. Denkschr. k.k. Akad. Wissensch., 1900, **68**, p. 869.

the cervical vertebrae. The latter, with the exception of the atlas, which remains adherent to the occiput, are not mentioned in the original description nor in any subsequent notice of the specimen. On the other hand, the principal features of the skull are well signalized by both Harlan and Cope, from the former of whom we quote as follows: —

"This interesting fossil consists of the skull, nearly complete, densely petrified, very weighty, tinged of a deep black, ferruginous color; characteristic marine fossil shells adhere to its base. . . . The external border of the superior maxillary bones is slightly broken on each side. Its discovery is due to the active researches of Mr. Francis Markoe, Jr., Corresponding Secretary of the National Institution, who obtained it from the Calvert cliffs, on the right bank of the Chesapeake bay, State of Maryland, along with other characteristic fossils. . . .

"The present specimen belongs to Cuvier's first subgenus, or "*les Dauphins à long bec*" [= type of Champsodelphis Gervais]. On comparison with the numerous species of living dolphins, it is found distinct from all of them. It approximates the Delphinapterus leucorampus, of Peron,[1] but differs in its various measurements, number of teeth, and in the arrangement of the palatine bones. . . .

"*Description of D. Calvertensis.* — In general outline, resembling other skulls of this genus. The head is proportionally narrower, and snout more elongated, than the Italian specimen with which I have compared it. The occipital and temporal ridges are strongly developed, indicating muscular strength, especially of the jaws. We find similar indications in the remains of the teeth, which have been large and robust. There are ten sockets remaining on the right side, with the teeth broken off at the rim. These organs approximate each other. The ten sockets include a line four and a half inches long. There has been about one and a half inches of the end of the snout broken off, which would afford room for two or three more teeth, making twelve or thirteen in all, on each side. The pyramidal eminence anterior to the posterior nares, on the palatine surface, is strongly pronounced. It terminates opposite the last tooth. The excavations or longitudinal grooves, on each side of the upper portion of this eminence, are unusually deep. The palatine surface is slightly convex transversely. Above, the head is narrower across the occipital ridges than other allied species, and narrower than the transverse diameter of the base of the skull. The ossa nasi are longer than broad, and convex. The atlas vertebra adheres to the occiput, above the condyles. It measures, across the transverse processes, five inches; transverse diameter, three inches; and the ring is about one inch thick." — (p. 196).

In connection with the above description, the following measurements are given, to which we have added their metrical equivalents in parentheses. The author states in regard to the missing portion of the rostrum that "one and a half inches must be considered as the length of the last portion of the extremity of the snout."

Dimensions:

Total length of head, from the temporal crest to the presumed extremity of the jaw	17 in. (432 mm.)

[1] *Vide* Cuvier, Ossemens Fossiles, **5**, pt. 1, p. 289, Plate **21**, Figs. 5 and 6, ed. 1823.

From the anterior border of the spiracles to the presumed extremity of snout	11.5 in. (292 mm.)
Breadth of skull above, across the occipital crests	5.0 in. (127 mm.)
Breadth at base, between the temporal bones	6.5 in. (165 mm.)
Longest diameter of largest tooth at the socket	0.35 in. (8.9 mm.)

Besides the foregoing, we may point out the following important characters whose combined weight is considered sufficient to establish beyond doubt the Platanistid relations of the form in question. (1) The cervical vertebrae are all free, and each one is of considerable length for a Cetacean; (2) the general form of the skull resembles that of Inia and Pontoporia (= Stenodelphis), but is relatively narrower behind, and has steeper lateral and posterior walls; (3) the large and nearly vertical parietals are widely separated from each other by the upward crowding of the supraoccipital, which is also wedged in between the frontals at the summit: in this region the frontals are visible only as narrow bands, continuous with the tumid nasals in front, enclosing the interparietal between them, and being themselves almost entirely concealed behind by the overroofing laminae of the maxillary elements; (4) the temporal fossa is large, and would appear to have been open in front; that part of the squamosal supporting the zygomatic process is very massive, and the orbital portion of the maxillary and frontal is correspondingly thickened; (5) the pterygoids are displaced from contact with each other in the median line through intervention of the vomer, and do not enclose an involuted air-space open behind; they entirely surround the palatines as in Inia and Pontoporia, and may have had (though this cannot be determined definitely from the present condition of the specimen) an articulation with the squamosal behind; the basal portion of the rostrum is wide and transversely arched; and (6), the premaxillaries, of extremely dense structure, are separated by a deep longitudinal cleft, and are broadly expanded without being inflated on either side of the narial orifices.

From the review already given it appears that, with the exception of Brandt and Abel, authors are agreed in including Lophocetus among Platanistids, but hold different opinions concerning which of the two subfamilies, Platanistinae or Iniinae, it is more nearly related. With Cope, we are persuaded that there is much greater structural resemblance to Inia and Pontoporia than to Platanista, among recent forms. The highly characteristic maxillary crests of the susu are not present in Lophocetus, the pterygoids do not unite in the median line to form an arch which almost entirely conceals the palatines, the latter do not extend in advance of the pterygoids along the basal portions of the rostrum, and the supraoccipital joins the parietals along crests that rise vertically and then flare slightly outwards, instead of being concave inwardly, as in the susu. On the other hand, as compared with Inia, only unimportant differences are found. The walls of the brain cavity are less rotund, the crests, as connoted by the generic name, are more powerfully developed, the nasals are crowded backwards so as to override the frontals at the vertex, which latter is divided by a deep longitudinal cleft, and the premaxillaries are more widely separated. The occipital condyles are rela-

tively broader in the fossil form than in Inia, but otherwise the bones forming the basicranial axis are remarkably similar. It is to be regretted that injury to the specimen prevents comparison of the bones in the orbital region, the zygomatic arch, and characters of the dentition. One can merely affirm that the teeth were single-rooted, and probably of cylindrical form, that is, without the additional tubercle shown by the posteriorly situated teeth in Inia. In so far as these latter may be said to recall something of the primitive condition of molars, whereas Lophocetus is homodont, the dentition of the Miocene genus is more specialized. But here we must not lose sight of the fact that Lophocetus is adapted to a marine, and Inia to a fluviatile habitat. The utility of a homodont-polyodont dentition to marine Carnivores, and the successive stages by which this condition is attained among Cetaceans, have been clearly demonstrated by Dames and others.[1]

In seeking for the nearest fossil allies of Lophocetus, attention is naturally directed first toward those forms which are regarded as standing in the immediate vicinity of Inia, possibly even in ancestral relations to the modern genus. Now a number of Tertiary forms are known whose characters accord in the main with those of Inia, and hence are properly included within the same subfamily. It may be doubted whether any of them fulfil the requisites of a direct ancestor of existing Iniinae, since they combine in their organization both generalized Cetacean characters, and also some others that indicate the animals were too specialized to be the progenitors of Inia. Among these Tertiary forms that present close structural resemblances to the modern type may be mentioned Iniopsis, from the Caucasian Eocene, the skull of which is incompletely known; several Platanistid species which are grouped by Abel under the new generic titles "Acrodelphis" and "Cyrtodelphis," from the European Miocene; and also the South American form described by Mr. Lydekker as *Argyrocetus patagonicus*. We should expect to find no less intimate resemblances between these forms and Lophocetus, on bringing them together.

Before undertaking comparisons, however, a word or two is necessary to explain the status and synonymy of the new names employed by Abel to designate practically the same grouping of species as was formerly included under Gervais's titles Champsodelphis and Schizodelphis. Both of these generic titles were suppressed by the Viennese author[2] in his memoir of 1899, and the names Acrodelphis and Cyrtodelphis substituted for them on the basis of newly

[1] Dames, W., Ueber Zeuglodon aus Aegypten. Pal. Abhandl., 1894, **5**, p. 212. — Fraas, E., Neue Zeuglodonten aus dem unteren Mitteleocän vom Mokattam bei Cairo. Geol. und Palaeont. Abhandl., n. s., 1904, **6**, p. 199–220. See also, concerning origin of polyodont dentition among Squalodonts, Kükenthal, W., Vergleichendanatomische und entwickelungsgeschihtliche Untersuchungen an Walthieren. Denkschr. Med.-Nat. Gesellsch. Jena, 1893, **3**, p. 421. — Weber, M., Studien über Säugethiere. Jena, 1886, pt. 1, p. 194–195.

[2] Abel, O., Untersuchungen über die fossilen Platanistiden des Wiener Beckens. Denkschr. k.k. Akad. Wissensch., 1900, **68**, p. 840.

defined differential characters, but without sensibly altering their respective contents. Thus, the type species belonging to the two older genera became in each case the typical species of the newly proposed genera. In other words, a valid generic distinction was recognized between two groups of fossil species for each of which a definite type was selected; and in each case the definite type so selected was identical with the type of a previously described genus. By this process of emendation and redefinition, the integrity of the older generic terms was not, and, according to ordinary rules of nomenclature, could not have been impaired. The genus Champsodelphis Gervais, typified by *C. macrogenius* (Laurill.) (=*C. macrognathus* Brandt), and represented by a number of other species as well, might be restricted, enlarged or otherwise modified, even broken up into several genera; but in the latter case the name Champsodelphis must be retained to designate that section which contains the original type of the genus. Similarly, in the case of Schizodelphis, so long as the typical species *S. sulcatus* Gervais is not proved to belong to any previously described genus, the original generic title must be retained, and no new one can be substituted in place of it. Therefore it becomes necessary to regard Abel's proposed title of Cyrtodelphis, having *S. sulcatus* Gervais for its type, as a synonym pure and simple of the older Schizodelphis, which has the same type species. In the case of Chamsodelphis, Abel has himself rectified his error of 1899 by restoring this name to good and regular standing. He restricts it in his Brussels memoir of 1905 so as to include only the type species, and employs the name Acrodelphis [1] as a collective designation for the nine or ten other species formerly embraced under Champsodelphis.

Some confusion exists as to exactly what constitutes the type species of Champsodelphis. Trouessart, in the quinquennial supplement, 1905, to his "Catalogus Mammalium," correctly indicates *C. macrogenius* (Laurill.) as the type. Abel, in his memoir published the same year, gives it as *C. macrognathus* Brandt. Both names refer to precisely the same thing. The extent of Brandt's changes was merely to restrict the application of Laurillard's title to the original of Cuvier's "Dauphin à longue symphyse de la mâchoire inférieure, déterré dans une sablière du département des Landes," and to found a new species, *C. valenciennesi*, upon a second specimen that Laurillard (and following him, Gervais) had associated with the type. Subsequently it was pointed out by Abel that the so-called *C. valenciennesi* of Brandt bore sufficient resemblance to Tursiops as to warrant its exclusion from Platanistids altogether. But instead of retaining Laurillard's well-founded specific name for Cuvier's original, he

[1] As pointed out by M. Trouessart (Revue Critique de Paléozoologie, 1906, **10**, p. 205), the genotype of Acrodelphis is *A. letochae* (Brandt). "Contrairement aux usages," continues this author, "M. Abel donne comme 'types' de ce genre *trois* espèces (*A. Letochae*, *A. Ombonii*, *A. denticulatus*). Il veut dire, sans doute, que ces trois espèces sont typiques." A discussion of methods of fixing the types of genera was introduced by Witmer Stone, in Science, 1906, **24**, p. 560, and continued by various other systematists.

adopts Brandt's altered designation of *C. macrognathus.*[1] This procedure is entirely arbitrary, and contrary to recognized principles of nomenclature. There is no other course than to regard *C. macrognathus* Brandt as a synonym of *C. macrogenius* Laurillard, and it is in this sense that the former name should be understood in those places where it occurs in the following passage. This quotation from Abel is made in order to allow readers the opportunity of judging for themselves whether we have correctly represented his position: —

"La grande incertitude qui régnait à l'égard du genre Champsodelphis, Gerv., m'a conduit, en donnant une liste des espèces de Schizodelphis, Gerv., et de Champsodelphis, Gerv., à renoncer à ces deux noms et à leur substituer deux autres genres, Cyrtodelphis et Acrodelphis. J'ai mis dans le genre Acrodelphis l'original du 'Dauphin à longue symphyse de la mâchoire inférieure, déterré dans une sablière du département des Landes,' de Cuvier, qui avait été décrit par Brandt sous le nom de *Champsodelphis macrognathus;* j'ai encore joint à ce genre les espèces suivantes: *Acrodelphis lophogenius*, Valenc., *Acrodelphis Ombonii*, Longhi, *Acrodelphis Letochae*, Brandt, et *Acrodelphis Krahuletzi*, Abel. . . .

"Mais des études prolongées sur les Odontocètes des dépôts tertiaires de l'Europe me font voir que le groupement proposé par moi, en 1899, n'est plus satisfaisant. J'ai eu l'occasion de comparer en détail les restes des espèces d'Acrodelphis du bassin de Vienne avec les types belges et les restes des formations miocènes du Nord de l'Allemagne, et je suis, maintenant, d'avis que la diagnose du genre Acrodelphis donnée en 1899 doit être plus restreinte qu'elle ne l'a été alors.

"Comme la mâchoire inférieure du *Champsodelphis macrognathus*, Brandt, se distingue absolument par sa taille et ses dents très espacées d'*Acrodelphis Letochae*, Brandt, et l'*Acrodelphis Ombonii*, Longhi; qu'en outre, la forme de la couronne est très différent dans les deux types; je suis d'avis que l'*Acrodelphis macrognathus*, Brandt, doit être consideré comme le représentant d'un genre différent d'Acrodelphis. Puisque le nom générique de Champsodelphis a été établi par Gervais pour la mâchoire inférieure des Landes qui a d'abord été decrité par Cuvier, mais que cette mâchoire inférieure est absolument différente des espèces décrites plus tard sous le même nom générique: *Champsodelphis* (*Acrodelphis*) *Letochae* et *Champsodelphis* (*Acrodelphis*) *Ombonii*, on doit conserver le nom de Gervais pour *Champsodelphis macrognathus*, tandis que le nom d'Acrodelphis doit rester pour les types beaucoup plus petits, armés de dents beaucoup plus serrées. . . .

[Les types de ces deux genres seraient:]

"1. *Champsodelphis*, Gervais. Type: *Champsodelphis macrognathus*, Brandt.

"2. *Acrodelphis*, Abel. Types: *Acrodelphis Letochae*, Brandt; *Acrodelphis Ombonii*, Longhi; *Acrodelphis denticulatus*, Probst."

Before passing from this subject of nomenclature, it will be instructive to glance at Abel's proposed grouping of Platanistids in general, as set forth in his recent

[1] The reasons proffered by Brandt in justification of this course are thus stated by him: "Ich schlage statt des Namens *macrogenius*, der ohnehin keinen rechten Sinn hat, den bezeichnenderen *macrognathus* vor, weil unter *D. macrogenius* Laurillard zwei Arten stecken, wie Valenciennes nachwies."

memoir. Most authors employ the term Platanistidae to include the two modern subfamilies of Platanistinae and Iniinae, together with the known fossil allies of either. The arrangement proposed by Dr. Theodore Gill in 1872 differs from the one commonly in vogue only in that the minor subdivisions are elevated to the rank of independent families. At that time the Iniidae alone were known to have fossil representatives, and even now opinion is divided as to which of the two groups some of the fossil forms should be referred. Abel's scheme is practically a revival of Gill's arrangement. In his latest memoir (1905) the family Platanistidae is restricted to the genus Platanista itself. The Iniidae of Gill are renamed Acrodelphidae, and made to comprise four subfamilies, one of which includes Delphinapterus and Monodon. In addition, two other independent families are recognized, one being typified by Eurhinodelphis, the other by Saurodelphis. All of these family divisions are considered to have equal rank with the Physeteridae, Ziphiidae, and Delphinidae, and to trace their origin back to Squalodon, but not to Zeuglodon, which is regarded as much too highly specialized to have been the direct ancestor of Squalodontidae. It is suggested that the latter were probably descended from small terrestrial Carnivores, and the Delphinidae from still another group, the Odontocetes being thus of diphyletic origin. Such, in brief, are Abel's more general conclusions.

In order to point out more clearly the exact equivalence between the so-called Acrodelphidae of Abel, and the earlier defined Iniidae of Gill, we may be permitted to reproduce the following summary given by the first-named author at page 129 of his memoir on Odontocetes: —

"Résumé général: Par les caractères de sa dentition et de son crâne, Cyrtodelphis se montre étroitement allié à Argyrocetus, Inia, Pontistes et Pontoporia, comme avec Acrodelphis, et doit donc former un même groupe avec ces formes. Ce groupe correspondrait partiellement aux Platanistides, dans les limites que Zittel a données à cette famille; mais, comme Platanista doit être éliminé, il faut choisir un autre nom. Puisque Acrodelphis est le type fossile le plus primitif de ce groupe, on devra se servir du nom de famille Acrodelphidæ. Nous aurons alors à distinguer:

"ACRODELPHIDAE.

"1. Sous-famille. *Argyrocetinae*: Argyrocetus, Cyrtodelphis, Pontivaga, Ischyorhynchus, Champsodelphis. [s. str.]
"2. " *Acrodelphinae*: Acrodelphis, Heterodelphis
"3. " *Iniinae*: Inia, Pontistes, Pontoporia.
"4. " *Beluginae*: Beluga, Monodon."

With regard to the last subfamily, which should properly be called Delphinapterinæ, the author makes the following observations: "Beluga et Monodon montrent de grandes ressemblances avec les Acrodelphides, tandis qu'ils diffèrent des Delphinides. J'ai, à cause de cela, considéré ces deux genres comme une sous-famille des Acrodelphides; leur origine n'est pas encore éclaircie. Les vertèbres cervicales libres prouvent qu'ils ne descendent pas des Delphinides."

We may now return to the principal matter at issue, namely, a comparison between Lophocetus and certain fossil genera which are regarded as standing in close relations with Inia, and are commonly assigned to the same subfamily. Now, the greater number of fossil Platanistids, or Iniidae in Gill's sense of the term, are remarkable for having the rostrum greatly elongated. In recognition of this fact, Abel divides his so-called Acrodelphidae into two sections, the first three subfamilies listed above being embraced in a section of 'Longirostres,' and the fourth, containing only Delphinapterus and Monodon, constituting the 'Brevirostres.' At first sight these longirostrate Platanistids would seem to present a marked difference from Lophocetus, for, as noted by Harlan, it does not appear that the rostrum in this form was greatly produced, and probably not more than a few inches are missing from it in its present condition. The solidity of the parts composing the muzzle, and general resemblance of the latter to that in brevirostrate Delphinoids, are in harmony with Harlan's conclusion, and so also are the facts of geographical distribution. Longirostrate Platanistids are especially characteristic of European Tertiary deposits, whereas on this side of the Atlantic forms like Champsodelphis,[1] Schizodelphis, Eurhinodelphis, etc., are conspicuously absent, being replaced, apparently, by brevirostrate genera. Probably the explanation of this fact is to be found in differences of physical conditions, such as are to be inferred from the different constitution of the faunas as a whole, and from the different nature of the sediments composing the deposits.

The Miocene deposits of the Middle Atlantic Slope in this country are of characteristically marine type, as indicated by both structural and fossiliferous evidence. On the other hand the corresponding Old World formations from which Delphinoid remains have been obtained are on the whole less clearly of marine origin, and the very circumstance that most of these Delphinoids are longirostrate has been interpreted in the light of adaptation to estuarine or even fluviatile conditions. For as shown by Dollo[2] and various other writers, it is precisely this modification that is oftenest met with in widely diverse orders of vertebrates where forms have become adapted to a littoral or fluviatile existence, as for instance, Lepidosteus among fishes, and Champsosaurus, Phytosaurs, and modern and extinct gavials among reptiles. Dr. J. H. McGregor,[3] in his memoir on the Phytosauria, calls attention to the striking resemblance of the rostrum to the snout of Lepidosteus, and quotes Fraas's observation that its decurved tip "perhaps demonstrates a habit of rooting in mud for food, and catching fishes." Cope,[4] also, noted a somewhat analogous formation of the rostral portion of the jaw in Anoplonassa, and offered a similar explanation. And more recently, the same conclusion has been put forward by Abel[5] in following language: —

[1] The reference to this genus of certain detached teeth and vertebrae from the Maryland Miocene must be regarded as provisional only.

[2] Nouvelle note sur le Champsosaure, Bull. Soc. Belge Géol., 1891, **5**, p. 153.

[3] Memoirs Amer. Mus. Nat. Hist., 1906, **9**, p. 38.

[4] Proc. Amer. Philos. Soc., 1869, **11**, p. 189.

[5] Mem. Mus. Roy. d'Hist. Nat. Belg., 1905, **3**, p. 154.

"Des museaux excessivement longs, tels que nous les trouvons chez Eurhinodelphis, Cyrtodelphis, Acrodelphis, Inia, Pontoporia et Platanista, paraissent être particuliers aux animaux fluviatiles, ou plus précisement, à ceux qui se servent de l'extremité du museau pour fouiller la vase et en faire sortir la nourriture miniscule qui y grouille tout comme chez les oiseaux a long bec (herons, cigognes, bécasses, etc.), oiseaux de marais et de rivages, dont le bec est, physiologiquement, non morphologiquement, identique aux longs rostres des dauphins fluviatiles. Le bec d'une bécasse est entièrement analogue au rostre de Pontoporia."

Enough has now been said by way of emphasizing the purely adaptive feature presented by the elongated rostrum of most Miocene Iniinae (Iniidae of Gill). Therefore, notwithstanding the marked difference in this respect which is exhibited by Lophocetus, we may still place all these forms in close association with the typical existing genus on account of mutual resemblances in other respects. It is unnecessary to enumerate here the various points of agreement that have been observed between Inia and leading longirostrate forms like Champsodelphis and Schizodelphis; for particulars one may refer to Abel's memoir of 1899, already several times quoted. These two genera, according to this author (p. 868), are very intimately related to Inia, but on the other hand Saurodelphis and Eurhinodelphis are more distantly related, and belong probably to a different evolutionary series. Accepting this conclusion, it is interesting to note that Lophocœtus displays rather close resemblances to the two first-named genera, and also to Acrodelphis in the restricted sense that the term is now understood by its author. Yet there is even closer affinity between Lophocetus and Inia itself. Schizodelphis and Eurhinodelphis are to be regarded as more primitive than the form we are considering, and more primitive also than modern Iniinae, in that the frontals take part to a considerable extent in forming the gently rounded summit of the cranium, where they are freely exposed, and are either wholly or partly separated from each other by the interparietal. But in Lophocetus the interparietal, which is fused with the steeply inclined supraoccipital, barely excludes the frontals from meeting in the middle line at the vertex of the cranium. Needless to say, too, that the disposition of the parietals in Lophocetus differs radically from that observed in Saurodelphis, where they retain more nearly their primitive arrangement and are in contact with each other in the median line. But as compared with Schizodelphis, the large extent of the parietal surface, the high vertical walls formed by these bones, and their powerful crests for the attachment of jaw muscles, show considerable likeness, and it is only in the more primitive arrangement of the frontals that this portion of the cranium differs very conspicuously in the two genera.

Neither Lophocetus nor any of the best known longirostrate genera resemble Eurhinodelphis in having such highly specialized characters as a completely closed temporal fossa and greatly thickened supraorbital ridges. Closed temporal fossae are the rule among Dolphins proper, Ziphioids, and the Physeteridae, but occur only exceptionally among fossil Platanistids. Like Eurhinodelphis, however, but unlike Inia and Iniopsis, there is no swelling or thickening of the pre-

maxillaries on either side of the narial openings, but these bones are flattened here, and rather widely expanded. Lophocetus shows the same squarish excavation of the maxillaries on either side of the vertex that occurs in modern Iniinae, and also in Pontistes and Iniopsis, but in none of these do the maxillary fossae have such prominent borders. A peculiar feature of Lophocetus, as compared with both recent and fossil Iniinae, is that the prominence formed by the nasals and frontals immediately behind the narial apertures is deeply cleft in a longitudinal direction. Moreover, in Inia this eminence is formed almost entirely by the frontals, which enclose the interparietal between their upturned borders posteriorly, and completely cover the nasals at the vertex in front. But in Lophocetus the frontals scarcely appear in this region, and the divided, nodulose nasals are conspicuously developed, alone forming with the mesethmoid the posterior wall of the external nares. This wall is relatively broader and less convex in a transverse direction than in Inia, but by no means presents the well-defined quadrate surface that is so strongly marked a feature of Iniopsis. The characters of the basicranial axis, and especially the arrangement of palatine and pterygoid elements, point to a closer relationship with Inia than with any known fossil form.

It is to be regretted that, owing to the imperfect condition of the specimen, comparisons cannot be made between Lophocetus and other Iniinae with respect to the dentition and extremity of the snout. One is perhaps permitted to infer from the general agreement in other respects that the dentition had become polyodont-homodont, and that teeth were still borne by the extremity of the premaxillary. The deep fissure separating these last-named bones in advance of the mesethmoid is probably without greater significance than the fused condition of the interparietal, both of which are regarded as old-age characteristics. On the whole, considerable reason is found for supposing Lophocetus to belong to the ancestral line from which modern Iniinæ are directly descended. Saurodelphis, on the basis of its dentition, would be regarded as more primitive than any of these forms, and Eurhinodelphis, with its edentulous premaxillary resembling that of Ziphioids, would be considered more highly specialized. Further material is necessary, however, before one can speak confidently in regard to the direct line of succession. We may conclude this part of the discussion by reproducing the scheme devised by Abel[1] for showing at a glance his views of phylogenetic and other relations.

[1] Mém. Musée Roy. d' Hist. Nat. Belg. 1901, **1**: 39.

PHYLOGENY OF ODONTOCETES.

Ziphius
Oligodont-pseudoheterodont
Pmx and *Mx* edentulous.

Mesoplodon
Oligodont-pseudoheterodont
Pmx edentulous, *Mx* with rudimentary teeth in the gums.

Ziphirostrum
Polyodont-pseudoheterodont
Pmx edentulous, *Mx* with functional teeth.

Eurhinodelphis
Polyodont-homodont
Pmx edentulous, *Mx* with functional teeth.

Pmx forming tip of rostrum.

Inia, Pontoporia
Polyodont-homodont.

Delphinus, "Cyrtodelphis,"
Polyodont-homodont, last vestiges of heterodont dentition among Delphinoids.

Phocaena, Neomeris
Polyodont-heterodont,
Pmx dentate.

Saurodelphis
Polyodont-pseudohomodont.

Neosqualodon, Squalodon
Polyodont-heterodont, *Pmx* dentate.

Microzeuglodon.
Oligodont-heterodont,
Pmx dentate.

We have substituted the genus Microzeuglodon, instead of Zeuglodon, as the initial member of the above series, in accordance with the author's most recent suggestion, published since the table first appeared. The opinion of most modern writers regarding the impossibility of viewing Zeuglodon as the ancestor of Squalodonts is accepted by Abel, who announces further the following general conclusions: —

1. The genus Squalodon is not descended from Zeuglodon.
2. The precursor of Squalodonts is to be sought for among small Archaeoceti, probably in Microzeuglodon.
3. The most primitive Squalodont known at present is Neosqualodon.
4. Microsqualodon represents a lateral offshoot of Squalodonts, transitional between the genera Acrodelphis and Delphinodon (which may be identical).
5. Under Squalodontidae are comprised very heterogeneous types, which should be clearly distinguished from one another.

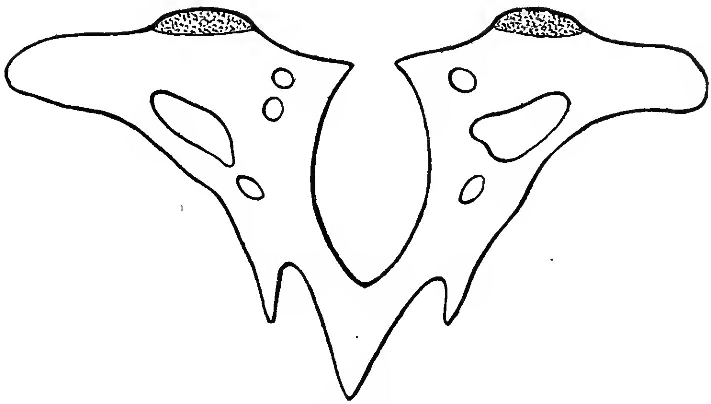


FIGURE *A*.

Transverse section across basal portion of rostrum of Lophocetus as provided by accidental fracture-line seen in Plate 1. × ½.

The more general features of the skull of Lophocetus have now been considered, and the relations they are presumed to indicate have been pointed out. A brief reference may be made here to the illustrations of the type specimen, before passing on to consider the series of cervical vertebrae preserved with the skull.

Plates **1** and **2** show respectively the dorsal and inferior aspects of the cranium, photographed from the actual specimen, and reduced to one-half the natural size. The two transverse fracture-lines appearing in the specimen, one slightly in advance of the position of the antorbital notch (the prominence for which is not preserved), and the other which forms the present termination of the muzzle, have been utilized for preparing the cross-sections shown in Figures *A* and *B*. In these will be noted the wide separation of the premaxillaries, these elements

being stippled in the drawing; the large sinus occupied by the mesethmoid cartilage; and the ample size of the longitudinal vascular canals. In the more posterior cross section (Fig. *A*), none of the sutures are distinctly marked, hence the relations of mesethmoid, pterygoids, and maxillaries at the base of the figure are best understood through comparison with the photograph of these parts given in Plate **2**. In the same plate will be noticed the extremely well preserved periotic elements, which have fortunately been retained in place, notwithstanding the loss of the tympanic bullae. The periotics are more elongate than the corresponding elements in Inia, with more bulbous promontory, and more strongly developed processes for attachment with the bullae. It is noteworthy that in both elements the stapes still remains seated in its proper orifice. The opening seen on the inner side of the periotics in Plate **2**, and also of the natural size in

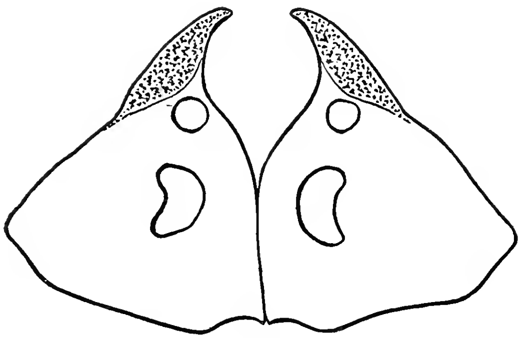


FIGURE *B*.

Transverse section of rostrum in the type of Lophocetus taken at line of fracture along which the forward extremity is severed off. × ½.

Plate **4**, Fig. 2, where a foramen normally occurs, leads directly into the cranial cavity; this is empty, and its walls may be viewed from behind through the foramen magnum.

The occipital border of the skull is indistinctly shown in both plates by reason of the fact that the atlas, within which is included also a portion of the axis, remains firmly cemented to the skull by matrix. It has been allowed to remain in this condition, as have also several characteristic shells (Turritella), to serve for purpose of identification with the original of Harlan's figures, and to leave no possible doubt that the series of cervical vertebrae about to be described belong to the same specimen. No mention of these latter has been made in any previous description. They are proved, however, to belong to the type specimen, by the fact that the axis has been fractured in such manner as to leave a portion of the centrum within the ring of the atlas, against which the remaining portion fits perfectly. The block of matrix in which the verbetrae are embedded without disturbing their natural position is shown in Plate **3**.

Cervical Vertebrae. — The entire series of cervicals is preserved, together with portions of the first three dorsals, all in natural association. Their features may be best described by saying that they reproduce in strikingly similar manner those of the corresponding structures in Inia, the resemblance being much closer than with any other genus. This similitude is found in the form of the individual vertebrae, their relative size, and arrangement with respect to each other, especially as regards the undulating overlap of the neural arches. Saving only that the atlas is more transversely elongate in Lophocetus than in the modern genus, it might be referred with equal propriety to either, if found in the detached condition. In both forms, the suboval ring of the atlas is of considerable thickness, with feeble neural spines and abbreviate transverse processes, the latter pointed slightly upward and outward, and provided below with a large flattened hypapophysial process for articulation with the axis, which has, of course, no distinct odontoid process. Owing to abrasion of the neural arch in the axis and third cervical vertebra, their spinous processes, such as they were, have been entirely destroyed; and the same is true for the last cervical and first three dorsals. All of the intervening cervicals, however, retain traces of very feebly developed neural spines.

On the under side of the series are seen in cross-section the stumps of the downwardly directed transverse processes, now broken off, belonging to the fifth and sixth cervicals. Their relations are apparently identical with those in Inia. On the inferior side, also, the size of the different centra is displayed to best advantage. Measurements taken here of these bodies are given as follows: —

Length of 1st cervical vertebra . . .	3.0 cm.	(approximately)
" 2d " "	2.0 "	"
" 3d " "	0.6 "	"
" 4th " "	0.8 "	"
" 5th " "	0.7 "	"
" 6th " "	0.8 "	"
" 7th " "	1.3 "	"
" 1st dorsal "	1.8 "	"
" 2d " "	2.3 "	"
Height of atlas	8.2 "	"
" axis	6.2 "	"
" 7th cervical vertebra . . .	6.4 "	"
Width of atlas including processes . .	12.4 "	"
" axis " " . .	10.0 "	"

Delphinus occiduus Leidy.

Plate 4, Fig. 1.

The second type specimen to be considered, although referred by Leidy, who first described it, unqualifiedly to the genus Delphinus, is to be understood rather as belonging to the group of Dolphins proper, that is, to the subfamily Delphinae, than as embraced within the more circumscribed limits of the typical genus. This

limitation is a necessary consequence of the fact that our only knowledge of the form is derived from a fragmentary portion of the rostrum, shown of the natural size in Plate **4**, Fig. 1. The original belongs to the J. D. Whitney Collection, presented to the Museum in 1895. It would be superfluous to add anything to Leidy's excellent description (Proc. Acad. Nat. Sci. Phil., 1868, p. 197), which is reproduced in the following paragraph: —

" *Delphinus occiduus.* — An extinct species is indicated by a fossil derived from the upper miocene formation of Half-moon Bay, California, submitted to my examination by Prof. J. D. Whitney. The specimen consists of an intermediate portion of the upper jaw, devoid of teeth, and encrusted with selenite. It measures along the more perfect lateral border 5 inches, and in this extent is occupied with 19 closely set, circular alveoli, rather over two lines in diameter. At the back of the fragment the jaw has measured a little more than 2 inches wide. From this position it gradually tapers for half its length, and then proceeds with parallel sides to the fore end, where it is $10\frac{1}{2}$ lines wide. The palate behind is nearly plane or slightly convex; at its fore part it presents a deep median groove, closed by the apposition of the maxillaries, and this groove is separated only by a narrow ridge from the alveoli. The sides of the maxillaries are slightly concave longitudinally, convex transversely. The intermaxillaries are broken away, leaving a wide, angular gutter between the remains of the maxillaries."

PLATE 1.

Lophocetus calvertensis (Harlan).

Calvert formation (Miocene); Calvert Cliffs Maryland. Type. Cranium viewed from the dorsal aspect, with atlas still engaged by matrix with occiput. Noticeable is the asymmetry of mesethmoid and nasals, and the longitudinal cleft dividing the nodulose summits of the latter, behind which are seen the flange-like frontals. $\times \frac{1}{2}$.

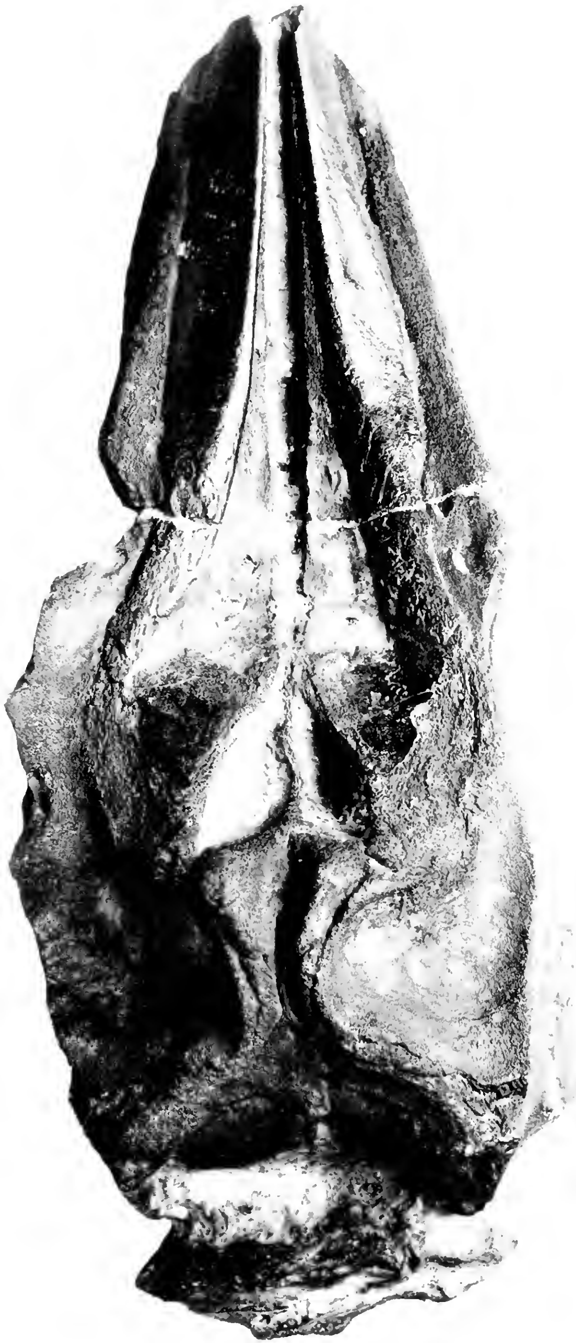


PLATE 2.

Lophocetus calvertensis (Harlan).

Calvert formation (Miocene); Calvert Cliffs, Maryland. Type. Inferior aspect of cranium with atlas still attached to occiput. Especially characteristic are the relations of palatine and pterygoid elements, the latter forming the so-called "pyramidal eminence" of Harlan, and the well-preserved periotic bones. × ½.

PLATE 3.

Lophocetus calvertensis (Harlan).

Calvert formation (Miocene); Calvert Cliffs, Maryland. Dorsal aspect of cervical vertebrae belonging to the type specimen. $\times \frac{1}{1}$.

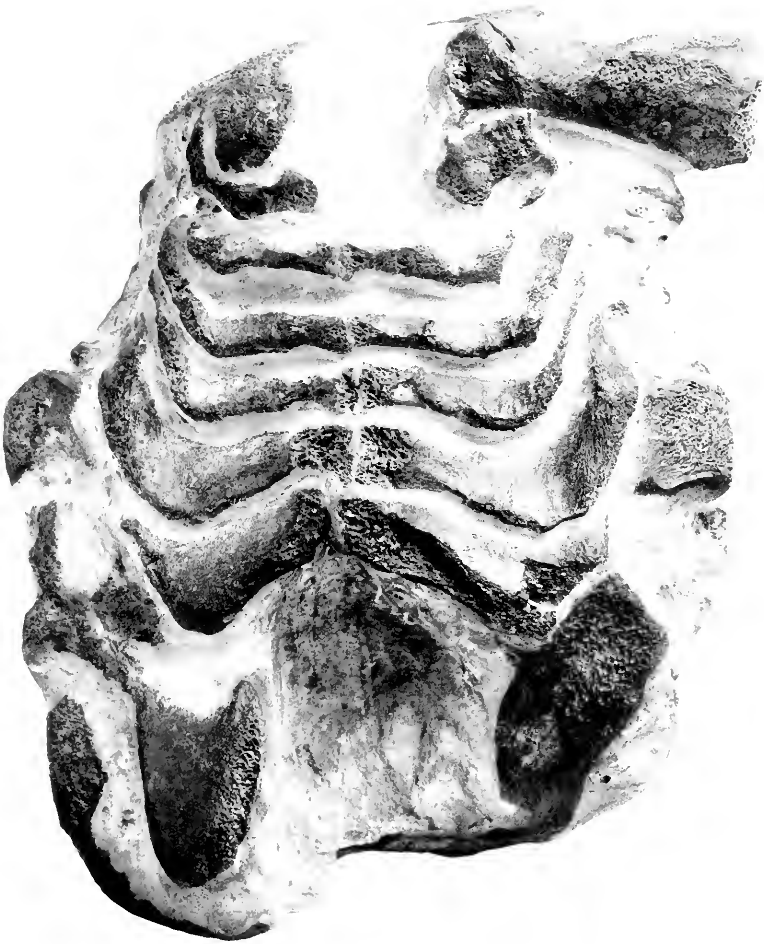
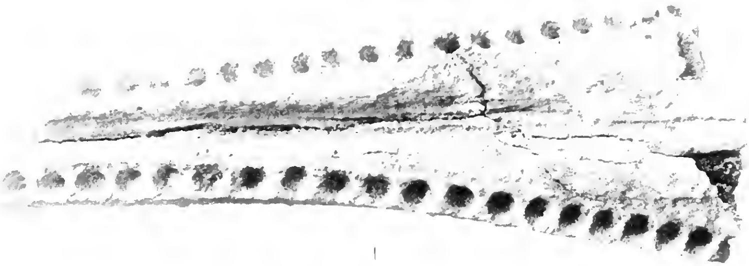


PLATE 4.

Fig. 1. *Delphinus occiduus* (Leidy). Miocene; Half-moon Bay, California. Type. Portion of rostrum. × $\frac{1}{1}$.

Fig. 2. *Lophocetus calvertensis* (Harlan). Calvert formation (Miocene); Calvert Cliffs, Maryland. Visceral aspect of left periotic, inverted, showing stapes preserved in place. × $\frac{1}{1}$.



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Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. LI. No. 4.

OBSERVATIONS ON THE TYPE SPECIMEN OF THE FOSSIL CETACEAN *ANOPLONASSA FORCIPATA* COPE.

By Frederick W. True.

With Three Plates.

CAMBRIDGE, MASS., U. S. A.:

PRINTED FOR THE MUSEUM.

July, 1907.

No. 4.— *Observations on the type specimen of the fossil cetacean Anoplonassa forcipata Cope.* By Frederick W. True.

I have recently had an opportunity of examining the type of the remarkable fossil cetacean *Anoplonassa forcipata* Cope, belonging to the Museum of Comparative Zoölogy. This specimen, on which the species was founded by Cope in 1869,[1] consists of the distal portion of a mandible, 191 mm. long. In the original description, Cope remarked that it was obtained, with remains of Mastodon, "not far from Savannah, Georgia." In 1890 he stated that it was from the "phosphatic deposits" of South Carolina.[2] His original description and figures are excellent, but the copies of the latter, published on a reduced scale in 1890, do not represent the specimen accurately. Faithful copies were published in Van Beneden and Gervais's Osteography of the Cetacea.[3]

Few cetologists have published any critical remarks on this interesting species and probably fewer still have ever seen the type and only known specimen. Cope, the original describer, was long in doubt as to its affinities, and, indeed, seems never to have come to a conclusion regarding them.

In 1869 he thought its relationships were with the "aberrant cetacea." "The nearest types," he remarked, "appear to be on the one hand Sirenia, and on the other, Squalodon."[4] In 1890 he actually placed it among the Sirenia, in the family Halitheriidae,[5] but cautiously remarked, "it is by no means certain that it belongs here, and it may be a Cetacean."

His remarks five years later (1895) indicate that he was then convinced that it was a cetacean and that it might be more or less closely related to the ziphioids. In describing his new genus Pelycorhamphus, which he assigns to the Choneziphiidae, he adds:

[1] Proc. Amer. Philos. Soc., **11**, p. 189, Plate 5.

[2] Amer. Nat., **24**, p. 700, Fig. 2. This apparent discrepancy may not be a real one, as Savannah is very close to the boundary line of South Carolina.

[3] Ostéographie des Cétacés, 1880, p. 386, text-fig.

[4] Proc. Amer. Philos. Soc., **11**, p. 189.

[5] Amer. Nat., **24**, Plate 700, Fig. 2.

"It would not be surprising if this genus should prove to be related to *Anoplonassa* Cope, which has the long symphysis mandibuli of the *Physeter*, with the nearly edentulous character of the Choneziphiidae." [1]

So far as I am aware, this is the final statement of Cope as regards Anoplonassa. The view that it was related to the ziphioid whales was not original with him, having been definitely published in Van Beneden and Gervais's Osteography, the title-page of which bears the date of 1880. On page 386 of that work, the authors remark: "We owe to Cope the description of a fossil fragment of a mandible of slender and elongated form, which comprises the greater part of the mandibular symphysis of a cetacean, without doubt related to (*voisin de*) *Hyperoödon* and *Ziphius*." [2]

It is to be noted that Leidy in 1869 assigned Anoplonassa to the Delphinidae, but with the statement that he accepted most of the fossil cetacean species on the authority of Cope, as he had neither time nor opportunity to examine the material on which they were based.[3] Leidy was probably influenced in this case by the view Cope held at the time, that Anoplonassa belonged to the "aberrant cetacea." Leidy's Delphinidae comprised all the Odontoceti, except Squalodon and its allies.

Brandt merely adopted the genus from Leidy, under the general heading of fossil delphinoids of North America.[4] Zittel merely cites the genus among the Ziphiinae,[5] being doubtless influenced by the opinion of Van Beneden and Gervais.

An examination of the type of Anoplonassa, and comparison of it with specimens of recent ziphioids in the National Museum, leave not the slightest doubt in my mind that it belongs to that group of cetaceans. It represents, however, a distinct section of the group. All recent ziphioids have the symphysis of the mandible comparatively short and the rami deep and compressed, while Anoplonassa has a very long symphysis, and it is highly probable that the rami were slender and rounded, somewhat as in Platanista. Although the ziphioids generally have a cranium with a long rostrum, externally the snout is quite short. In Anoplonassa, the snout was doubtless elongated, as in such forms as Platanista and Stenodelphis.

[1] Proc. Amer. Philos. Soc., **34**, p. 138.
[2] Ostéographie des Cétacés, 1880, p. 386.
[3] Journ. Acad. Nat. Sci. Phil., 1869, p. 436.
[4] Mem. Acad. St. Petersburg 1873 (7), **20**, p. 289.
[5] Handbuch der Paläontologie, 1893, **4**, Vertebrata, p. 179.

The chief features of the mandible of Anoplonassa are as follows: (1) Its slenderness; (2) the slight depth of the symphysis in proportion to its length, and the strong convexity of its sides; (3) the upturned and expanded termination; (4) the pair of large, nearly round, and very slightly depressed terminal alveoli; (5) the rudimentary alveolar groove, with its pair of rather small and shallow elliptical alveoli, not far distant from the terminal pair; (6) the large size and peculiar disposition of the inferior terminal foramina.

It is a well-known fact that in Mesoplodon and other existing genera of ziphioids, the superior alveolar border of the mandible in young individuals, at least, presents a shallow, more or less rudimentary, alveolar groove, and that in a certain proportion of specimens there are, in addition to the 2 or 4 large teeth, a number of very small, rudimentary teeth, which are imbedded in the integuments, and rest on, or partly in, the groove.

The groove itself occupies rather more than the anterior half of the superior border of the mandible. In Mesoplodon it is interrupted by the deep alveoli of the single pair of large teeth, which in most species are at a considerable distance from the anterior end of the mandible. In young specimens of Berardius, a genus with four large teeth, the interspace between the anterior tooth and the posterior tooth on each side is extremely small, and the rudimentary alveolar groove really begins behind the posterior tooth. In adults, however, the diastema between the anterior and posterior deep alveoli may be as much as 70 mm. This interspace is not depressed, but is rough and pierced by several canals.

In a mandible of *Ziphius cavirostris* 770 mm. long, the alveolar groove has a maximum width of about 9 mm. and a maximum depth of about 5 mm. In another imperfect mandible of Ziphius from an old individual the groove is deeper, especially anteriorly. The maximum depth is about 11 mm. In all the ziphioid mandibles examined, the groove is the broadest at the anterior and posterior ends. The floor of the groove is very uneven, and is pierced by numerous foramina for nutrient vessels and nerves. The edges of the groove in some specimens are quite smooth and straight. In others they are more or less crenulate, producing here and there the appearance of genuine alveoli, but these depressions never have the depth or the regular form of the alveoli of the large teeth.

The groove above described is found in Anoplonassa, with a similar general conformation and relative size. The walls, however, are more strongly crenulate than in specimens of existing ziphioids I have examined.

The opposite walls approach each other more frequently, and in a few places are bridged by transverse septa almost on the level of the superior surface. The groove has in consequence somewhat the appearance of a succession of shallow, elongated alveoli. Except at one point, however, it is improbable that any teeth were implanted in the jaw posterior to the large terminal pair, though some small rudimentary teeth may have been, and probably were, imbedded in the integuments above the groove, as in many specimens of recent ziphioids. At the point on the alveolar groove of Anoplonassa already referred to, at a distance of about 47 mm. posterior to the large terminal alveolus, is a second smaller and shallower one of an elliptical form. On the left side this has a length of about 13 mm., a width of about 7 mm., and a depth of about 3 mm. The floor has a granular appearance similar to that of the anterior alveolus. There can be no doubt that a pair of teeth was originally implanted in the jaw at this point, similar to, but much smaller than, the anterior pair, Anoplonassa in this respect resembling Berardius.

The large anterior pair of alveoli is situated immediately at the tip of the mandible. They occupy the whole width of the extremity of the jaw, which is considerably expanded to receive them. They are separated by a common median wall only about 4 mm. in breadth. Each alveolus is about 23 mm. long, 16 mm. broad, and has a maximum depth of about 5 mm. In the centre of each depression is a papilliform elevation. The whole floor of the alveolus is granular in appearance, as already mentioned, and consists of a fine bony network, surrounding small vascular openings. In these alveoli a pair of large teeth undoubtedly rested, as in Ziphius or Berardius. It is well known that in young ziphioids, and especially in the two genera just mentioned, the teeth are implanted in very deep alveoli, with only the tip projecting above the superior surface of the mandible. As the teeth grow they are pushed out more and more, so that finally their roots are scarcely at all below the superior surface of the jaw. In the meantime the vascular pulp below them ossifies and fills the alveolar cavity almost to the top, and on the upper surface of this bony network rests the root of the mature tooth.

This last stage is shown in the mandible of an adult Ziphius (Cat. No. 49599), from Newport, R.I., in the U. S. National Museum. Here the large anterior alveoli are filled to within about 12 mm. of the free margins with a spongy mass of bone, the upper surface of which is somewhat depressed.

The anterior alveoli of an adult *Berardius bairdii* from Bering Id. present a similar appearance on a larger scale. The resemblance of these

alveoli to those of Anoplonassa is very striking and is, I think, the result of a similar mode of dental growth.

The fragment from the anterior end of the symphysis of the mandible which constitutes the type of Anoplonassa, is nearly straight in its posterior two-thirds, but the tip is quite sharply curved upward, and, as already stated, considerably expanded. Just behind this expanded portion, the jaw is slightly constricted. These characters are, strictly speaking, peculiar to Anoplonassa as compared with recent ziphioids, but in adult or old specimens of Ziphius the superior surface of the symphysial region is curved upward, as in Berardius, although this surface is plane, the end of the jaw is rounded, and the terminal alveoli are directed upward rather than forward.

In cross-section, the type of Anoplonassa is shield-shaped, or rather, triangular, with one plane side (superior) and two convex sides. The chord of the convex sides of the jaw does not exceed the breadth of the superior surface, or in other words, a cross-section of the jaw has nearly the form of an equilateral triangle. On casual examination, it would appear that in Anoplonassa the symphysis is not as deep in proportion to its breadth as in existing ziphioids, but a comparison of measurements shows that in Mesoplodon and Berardius the breadth of the extremity of the jaw is about as great as its depth, and in adult Ziphius the breadth is considerably greater than the depth. It thus becomes obvious that it is not the breadth of the symphysis that makes the jaw of Anoplonassa seem so slender, but its great length. The appearance of the specimen indicates that only a portion of the symphysis has been preserved, and that the whole symphysis was much longer. Even in the fragment, however, the length is 6 times the depth, while in Ziphius and Mesoplodon the length of the complete symphysis is only from $2\frac{1}{3}$ to $5\frac{1}{2}$ times its greatest depth, and in Berardius but 2 times its depth.

It is difficult to conjecture how long the complete symphysis of Anoplonassa was originally, or what was the length of the entire mandible. That the symphysis was much longer than the fragment preserved is, as already stated, extremely probable, since the width at the posterior end of the fragment is only 7 mm. greater than the width immediately behind the posterior pair of alveoli. It is certain that the general conformation of the mandible must have been very different from that of any existing ziphioid, and that it resembled rather the mandible of a sperm whale (Physeter), or of one of the Plantanistidae, such as Platanista or Stenodelphis. If the upper jaw was equally

slender, the head must have resembled that of such long-beaked forms as Platanista, but if the maxillae were expanded, which is improbable, the head itself may have been broad and obtuse, as in Kogia or Physeter, and the lower jaw small and underhung. In either case, the appearance of the animal would be very different from that of any of the existing ziphioids, in which the snout is comparatively short and thick, or, in other words, of the shape commonly called "bottlenosed."

In Anoplonassa, the vessels and nerves which supply the mandible instead of issuing anteriorly through a number of foramina scattered irregularly along the rami in the vicinity of the symphysis, as is usual in some ziphioids and most Delphinidae, emerge close to the tip of the jaw in a nearly symmetrical fashion, there being two large foramina on each side immediately below the alveolus of the terminal tooth, with a smaller one between them. The foramina of each side are joined posteriorly by a quite deep groove, which runs along the inferior surface of the jaw nearly to the end of the fragment. The symphysis is strongly carinate in the median line, the internal edge of each half of the jaw being raised into a prominent ridge, which forms the inner boundary of the groove already mentioned. The keel extends from the tip of the mandible nearly to the end of the fragment, but fades out gradually posteriorly.

A very similar arrangement of foramina and ridges occurs in Ziphius and in Berardius. In the former genus the ridges forming the keel are shorter, and somewhat divergent. The canals extending backward from the anterior terminal foramina are much less strongly developed than in Anoplonassa and run into a large and sharply defined mental foramen, situated in line with the posterior end of the symphysis. The anterior foramina instead of remaining separate, are usually merged together, forming an opening of considerable size.

The conformation of Berardius is similar to that of Ziphius, except that usually the mental foramen assumes the form of a long trough situated a little in front of the posterior end of the symphysis and followed posteriorly by one or more additional foramina. It is probable that at the posterior end of the symphysis of Anoplonassa there was a similar foramen or trough. That it is not found on the type specimen is an additional indication that the posterior end of the symphysis is lacking.

While the form of the alveoli, alveolar groove, and mandibular foramina of Anoplonassa denote clearly that it belongs to the subfamily Ziphiinae, it obviously represents a section of that subfamily distinct

from the section to which the recent genera belong. Leaving out of consideration other fossil forms presently to be mentioned, one might properly separate the Ziphiinae from the Physeteridae and, following J. E. Gray, give them the full rank of a family. The family would be divided into three sections, consisting respectively, (1) of Hyperoödon, (2) the other recent genera, and (3) Anoplonassa.

Very recently Dr. O. Abel has called attention to three fossil forms [1] two of which at least are somewhat closely allied to Anoplonassa. These are *Palaeoziphius scaldensis* (Du Bus), *Cetorhynchus atavus* Abel and *Mioziphius belgicus* Abel, all from the Upper Miocene of Antwerp. Of these, *P. scaldensis* is considered by Abel to be the oldest. The size of the mandible is about the same as in Anoplonassa. The length of the entire symphysis in proportion to its depth is about the same as the length of the fragment of the symphysis of Anoplonassa to its depth. Palaeoziphius, however, has 14 alveoli on each side, between most of which are well-formed septa whose upper surface is in the same plane with the upper surface of the jaw. Dr. Abel states that the anterior end of the jaw is slightly expanded, but the figure which accompanies his description does not indicate such an expansion, and we may suppose that it is at best only slight. It is also stated that the symphysial region is semicircular in transverse section and that the end of the jaw is turned upward.

In Cetorhynchus, which is larger than Anoplonassa, the alveolar groove is rudimentary and the septa are imperfect and do not reach the level of the upper surface of the jaw. This upper surface is concave, while on the sides of the mandible there is a deep mental groove. The transverse section of the jaw is semicircular.

In *Mioziphius belgicus* the mandible is much more slender than in Cetorhynchus, but, judged by the symphysial region, is about a half larger than Anoplonassa. Instead of a series of well-formed, or imperfect, alveoli, it has a narrow and shallow rudimentary alveolar groove and two pairs of very large alveoli resembling those of Anoplonassa very closely in some particulars, though the second pair is larger in proportion to the terminal one than in that genus. The terminal alveoli are filled with a mass of cancellous tissue which has a concave surface and a central eminence, as in Anoplonassa, and the alveoli themselves are separated by a narrow median partition. The jaw is expanded at the end where these alveoli are situated. The mass in the posterior alveoli, beside filling the cavity of the latter, appears to protrude considerably

[1] Mém. Mus. Roy. Hist. Nat. Belg., 1905, **3**.

beyond the upper surface of the jaw, and in this respect as well as in the larger size of the alveoli themselves, the specimen departs widely from Anoplonassa. I cannot discover that Dr. Abel has given any information regarding the depth of the mandible, but he states that the symphysis is short. In the figure which accompanies the description the jaw is $\frac{1}{4}$ wider at the line of the posterior end of the symphysis than immediately behind the anterior alveoli.

As regards the relations of *Palaeoziphius scaldensis* to *Anoplonassa*, Dr. Abel remarks: —

"The genus *Anoplonassa*, from the Phosphate Beds of Savannah (Georgia), represents a phase of development in which the alveolar canals of the mandible have become rudimentary, with two pairs of teeth [*i. e.*, alveoli] close together; the anterior terminal pair is twice as large as the second pair, which is situated at about the middle of the length of the symphysis. The jaw recalls that of *Squalodon* in general form.

"Although one may without hesitation unite *Anoplonassa* with the ziphioids, until now those stages (of development) have been lacking which lead from *Anoplonassa* to the oldest polyodont and homodont ancestors of the ziphioids. This intermediate form is now represented by the type that Du Bus has described under the name of *Chamsodelphis Scaldensis* [= *Palaeoziphius scaldensis* (Abel)].

"In a comparison with *Anoplonássa* the agreement in size, the length of the symphysis, and the upward inflection of the anterior extremity [of the mandible] immediately strike the eye; the jaw from the Antwerp Boldérien also recalls that of *Squalodon*. But that which at once clearly distinguishes the Antwerp jaw from that of the Phosphate Beds of Savannah, Georgia, is the presence of 14 alveoli in each half of the symphysis." [1]

The foregoing quotation appears to indicate that Dr. Abel considers Palaeoziphius the nearest known ally of Anoplonassa, and hence more closely related to it than are Cetorhynchus or Mioziphius. The reasons which induce him to assign Palaeoziphius to the Ziphiidae are not stated in his paper, so far as I can discover, except as appears in the comparison with Anoplonassa above quoted. The resemblances between the two genera therein mentioned are: (1) the approximately equal size, (2) the expansion of the end of the mandible, (3) its upturned extremity.

As already alluded to, the size of the mandible is somewhat larger in Anoplonassa. The symphysis is certainly somewhat longer, and probably much longer. The expansion of the end of the mandible is much greater; indeed, in Palaeoziphius it is so slight as not to be appreciable in the figure given by Dr. Abel. It is true that Anoplonassa has the

[1] *Loc. cit.*, (1905), p. 92.

end of the jaw upturned, but this is quite probably an age character, as in the recent genus Ziphius old individuals have the extremity of the jaw strongly recurved, while in young individuals the angle between the axis of the symphysis and the axis of the rami is very obtuse.

It appears to me that the evidence that Palaeoziphius belongs to the ziphioids is not convincing, though it is conceivable that the ancestors of the recent genera may have been some such form with a series of functional teeth. It has to be remembered that Palaeoziphius, Cetorhynchus, and Mioziphius are all from the upper Miocene, and that Anoplonassa was also probably derived from the Miocene.

In my opinion Mioziphius is a much nearer relative of Anoplonassa than is Palaeoziphius. That it is of larger size and has a shorter symphysis does not seem to me to exclude the idea of close relationship. It is a well-known fact that closely allied recent genera of cetaceans, such as Steno and Sotalia, or Steno and Tursiops, among the Delphinidae, differ greatly in the two characters mentioned. In the genus Mesoplodon the length of the symphysis varies very considerably in different species. In the general conformation of the symphysis, in the general form, details of structure, and relative positions of the alveoli, and in the form of the end of the jaw, Mioziphius certainly exhibits a striking resemblance to Anoplonassa. These characters, I think, greatly outweigh those of size and of length of symphysis, and make it proper to unite the two genera in a separate section of the Ziphiidae.

Certain crania, as well as mandibles, are assigned to *Mioziphius belgicus* by Dr. Abel, though he does not give the evidence on which the reference of the former to that genus and species is based. Presuming that these crania and jaws really do belong to the same species, it will be interesting to consider Cope's view, expressed in 1895, that the cranium known as Pelycorhamphus may belong to the same genus as the jaw known as Anoplonassa.[1]

Cope's description of the cranium of Pelycorhamphus indicates a form sharing some of the characters of Choneziphius, with others of Paracetus, Kogia, etc., and having as a peculiar feature the expansion of the proximal end of the vomer, forming a wide basin which overlaps the maxillary. There appears to be some trace of this latter character in *Mesoplodon layardi*, but nothing resembling it occurs in Mioziphius. It seems, therefore, that if Dr. Abel has correctly associated the mandible No. 3854 of the Brussels Museum with the cranium of Mioziphius, Pelycorhamphus has nothing to do with Anoplonassa. I am by no means

[1] Proc Amer. Philos. Soc., 1895, **34**, p. 138.

convinced, however, that such is the case, but believe that Cope's surmise may prove correct. Until more material is collected, the question at issue cannot, I think, be satisfactorily settled.

The dimensions of the type specimen of *Anoplonassa forcipata* are as follows: —

Total length	191 mm.
Greatest breadth at the posterior end	34
" " at the anterior end (across the centre of the anterior pair of alveoli)	34
Least breadth behind the anterior pair of alveoli	27
Breadth across centre of posterior " " "	32
Vertical depth at posterior end of fragment	29
" " opposite the posterior pair of alveoli	26
" " " the hind margin of the anterior pair of alveoli	30
Greatest breadth between inner margins of rudimentary alveolar canal posteriorly	24
Breadth between the same, midway from anterior to posterior pairs of alveoli	16
Least breadth between posterior alveoli	14
" " " anterior alveoli	4
Length of posterior alveolus (left)	13
Breadth " " "	7
Length of anterior alveolus (left)	23
Breadth " " "	16

PLATE 1.

Anoplonassa forcipata Cope. Holotype. Superior aspect.

HELIOTYPE CO., BOSTON.

PLATE 2.

Anoplonassa forcipata Cope. Holotype. Inferior aspect.

HELIOTYPE CO., BOSTON.

PLATE 3.

Anoplonassa forcipata Cope. Holotype Lateral aspect.

HELIOTYPE CO., BOSTON.

Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. LI. No. 5.

PRELIMINARY REPORT ON THE ECHINI COLLECTED IN 1906, FROM MAY TO DECEMBER, AMONG THE ALEUTIAN ISLANDS, IN BERING SEA, AND ALONG THE COASTS OF KAMTCHATKA, SAKHALIN, KOREA, AND JAPAN, BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," IN CHARGE OF LIEUT. COMMANDER L. M. GARRETT, U. S. N., COMMANDING.

By Alexander Agassiz and Hubert Lyman Clark.

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October, 1907.

No. 5 — *Preliminary Report on the Echini collected in* 1906, *from May to December, among the Aleutian Islands, in Bering Sea, and along the coasts of Kamtchatka, Saghalin, Korea, and Japan, by the U. S. Fish Commission Steamer "Albatross," in charge of* Lieut. Commander L. M. Garrett, U. S. N., *Commanding.* By Alexander Agassiz and Hubert Lyman Clark.

The "Albatross" sailed from San Francisco *via* Seattle[1] to Dutch Harbor, Alaska; thence to the westward among the Aleutian Islands, swinging northward and back again to take in Bowers Bank in Bering Sea; from the end of the Aleutian chain northwestward to the Komandorski Islands, then to Petropaulovsk, Kamchatka; thence rounding the southern point of this peninsula and up its western coast to Lat. 51° 40′; from this point southwestward to the Okhotsk Sea along the Kuril Islands to Hakodate, whence the course was taken along the western coast of Hondo, crossing the Sea of Japan to the Korean coast; thence zigzagging southward among the numerous islands at the lower end of the Japanese archipelago, including the northern Linschotens; northward along the eastern Japanese coast, through the Inland Sea and along the outer coast of Hondo again to Hakodate, thus completely circumnavigating Hondo and Kiushiu. From Hakodate the ship cruised northward, west of Hokkaido, up the western coast of Saghalin Island to Lat. 47° 40′; returning and rounding the lower end of the island to Cape Patience, on the eastern side; from Cape Patience south again to the eastward of Hokkaido and back to Hakodate, returning thence to Yokohama, from which point, after a short cruise in Suruga and Sagami bays, the vessel sailed for San Francisco.

The collection of Echini made by the "Albatross" from May 3 to December 10, 1906, is interesting, as it connects the fauna of the deep waters of Alaska and off the Aleutian Islands with that of Japan. The collection from Japanese waters is important, as with those made by Döderlein, we now have a good representation of Japanese Echini living

[1] The route of the "Albatross" is taken from Dredging and Hydrographic Records of the U. S. Fisheries Steamer "Albatross," for the year 1906. Washington, 1907.

in moderate depths, *i. e.*, less than 1000 fathoms. The bulk of the collection from Japan is inside of 300 fathoms; at a few points only was the dredging carried below 700 fathoms. Consequently this collection, like that of Hawaiian Echini we have under examination, fails to connect the littoral with the deep sea fauna.

But as regards the so-called continental region, there are some interesting points of comparison between the Japanese, the Hawaiian, the Alaskan, and the Panamic faunae. In the Panamic fauna there are but few species which encroach on that region either from the North or the South; it has a most typical Echinid fauna connecting with the deep water and abyssal region in which we find the Cystechinidae, Urechinidae, Palaeopneustidae, Ananchytidae, and the like; the nearest relatives of the Panamic Echinid fauna being mainly Indo-Pacific and Pacific species of wide geographical range. We have already called attention to the geographical relation of the Echini collected[1] in the Hawaiian region, which are in the main Pacific and Indo-Pacific.

The Japanese collections indicate affinities with some of the Hawaiian Echini. The absence of Cidaris proper and of the widely spread species of Pacific Echinometra, like *E. mathaei*, *picta*, and *oblonga* and of Diadema, is quite striking. We have only Dorocidaris and Stereocidaris common to both the Hawaiian Islands and Japan. Of the Salenidae of Japan, one extends to Hawaii. A new species of Coelopleurus and the presence of *Aspidodiadema tonsum* indicates the East Indian affinities of Japan. Echinothuriae are common in Japanese waters; one of the species of Asthenosoma is found in 39 fathoms; Phormosoma from 250 to 918, and Sperosoma from 500 to 1766 fathoms. One of the species of Phormosoma from Japan is also found at the Hawaiian Islands. The number of species of Sperosoma is remarkable. The species of Japanese Strongylocentrotus indicate northern Pacific affinities. The species of Temnopleuridae are either identical with (Prionechinus) or allied to (Genocidaris, Pleurechinus) East Indian species. The occurrence of *Hemipedina mirabilis* and of *Phymosoma crenulare* is most interesting. The Japanese collections contain no Hipponoë and only one species of Echinus. It is, however, marked, as is the Hawaiian collection, by the number of its Clypeastroids, especially Laganum of East Indian types, and Scutellidae of Atlantic and northwestern Pacific genera.

A new Echinolampas has been obtained. The only Pourtalesia is *P. laguncula*, which, judging from some fragments, grows to a larger size than was previously known. In the deep waters of the Bering Sea and

[1] Bull. Mus. Comp. Zoöl., 1907, Vol. L, No. 8, p. 232.

off Japan were found Urechinus and Cystechinus, and among Palaeopneustidae one species of Meijerea is common to Bering Sea and the Hawaiian Islands. Among the Spatangina we find Gymnopatagus, Lovenia, and Pseudolovenia, both in Japan and the Hawaiian Islands. *Spatangus Lütkeni* of Japan is closely allied to *S. paucituberculatus* of the Hawaiian Islands. *Brissopsis Oldhami* and *luzonica* have a wide range including both Japan and the Hawaiian Islands, and the genus Aceste is also common to both regions. It is interesting to note the occurrence of two species of Echinocardium, of Hemiaster and of Periaster; the last genus is also found in the Hawaiian Islands. A striking difference between the Japanese and Hawaiian faunae is seen in the abundance of Schizasters in the former region and their almost complete absence in the latter. While our Hawaiian collection contains only a single, very small specimen, there are several hundred in the collection from Japan.

It may be of interest to note that of the 49 genera taken by the "Albatross" in the Hawaiian region, only 20 were taken also in Japanese waters, and of the 67 species, only 9 are in the Japanese collection.

DESMOSTICHA Haeckel.

CIDARIDAE Müller.

Dorocidaris Reini Död.

Cidaris (*Dorocidaris*) *Reini* Döderlein, 1887. Jap. Seeigel, p. 7; Taf. 4, figs. 1–7, Taf. 8, figs. 4a–d.

There is a single adult specimen from station 4933. We also refer to this species two young Cidaridae, one 9, the other 13 mm. in diameter, from station 4936. These individuals are remarkable for their short, stout primary spines, which only about equal the diameter of the test and are noticeably swollen above the neck. They are provided with ten or twelve longitudinal ridges but these are not at all serrate, nor is there any indication of granules or prickles anywhere on the spine. These peculiar primaries are yellowish-white, tipped with brown and with two broad rings of the same color. They are unlike the spines of any Cidaroid which we have seen and it is possible that the two specimens are really the young of an hitherto undescribed species.

Station 4933. Off Kagoshima Gulf, Japan, 152 fathoms.
" 4936. Off Kagoshima Gulf, Japan, 103 fathoms.
Three specimens.

Stereocidaris microtuberculata Yosh.

Cidaris (*Stereocidaris*) *microtuberculatus* Yoshiwara, 1898. Ann. Zoöl. Jap., **2**, p. 57.

There is a single specimen of this species, which is notable for its large size. The horizontal diameter measures 86 mm., which is considerably more than that of any specimen of Stereocidaris hitherto recorded. Yoshiwara's largest specimen of this species measured 66 mm. As the pedicellariae have never been described, it may be said here that they are very similar to those of *S. leucacantha* A. Ag. and Cl. and cannot be distinguished from them with certainty. The globiferous, both large and small, are very abundant, but the tridentate seem to be very rare.

Station 4807. Between Hakodate and Sado Island, Japan, 44–47 fathoms.

One specimen.

Stereocidaris sceptriferoides Död.

Cidaris (*Stereocidaris*) *sceptriferoides* Döderlein, 1887. Jap. Seeigel, p. 5, Taf. 2, figs. 12–17, Taf. 8, figs. 3a–e.

This rare species is represented by a single small specimen, which agrees well with Döderlein's description and figures, except that the secondaries are not pure white but are tinged with brown, and the test is distinctly brown. Döderlein's figures of the pedicellariae, although not incorrect, do not do justice to their remarkably slender form. Moreover, in many of them the valves have a conspicuous unpaired end tooth and the opening is about one-third of the length. They are thus almost identical with those Mortensen figures as characteristic of his new genus, Schizocidaris. **1903**, Ingolf Exp. Ech., Pt. I, Pl. 10, figs. 25 and 28. If that genus is to be recognized, this species must certainly be placed in it, although it is in other respects very evidently a Stereocidaris.

Station 4968. Between Kobe and Yokohama, Japan, 253 fathoms.

One specimen.

Anomocidaris japonica A. Ag. and Clark.

Dorocidaris japonica Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 76.

Cidaris (*Stereocidaris*) *japonica* Döderlein, 1887. Jap. Seeigel, p. 6, Taf. 3, figs. 1–20; Taf. 8, figs. 1a–h.

Cidaris (*Stereocidaris*) *tenuispinus* Yoshiwara, 1898. Ann. Zoöl. Jap. **2**, p. 57.

Anomocidaris tenuispina A. Agassiz and Clark, 1907. Haw. Pacif. Ech. Cid., p. 30; Pl. 11, figs. 6–12, Pl. 12, figs. 18–30, Pl. 31, figs. 5–8.

A large series of this interesting species was taken and we are therefore able to give additional information about it. The conical form of the test shown by the single specimen formerly at our disposal is not characteristic but is found to a greater or less degree in several individuals, none of which, however, are fully grown. The large specimens all have the rounded abactinal surface figured by Döderlein for *japonica* and a careful comparison of Döderlein's description and

figures with Yoshiwara's description and with our numerous specimens, ranging from 11 to 40 mm. in diameter, has satisfied us that *japonica* and *tenuispina* are identical. But we retain the genus Anomocidaris on account of the bare abactinal surface, which is different from that of any other Echinoid in the absence of primary tubercles on the upper coronal plates. In small examples of Stereocidaris and other Cidaridae, on the youngest coronal plate, next to the abactinal system, a primary tubercle is formed which increases in size with the growth of the plate and sooner or later bears a primary spine; in the adult, therefore, the uppermost coronal plate has an imperfect tubercle, the second has a more perfect tubercle which usually carries a spine and the third always has a primary spine. In small examples of Anomocidaris (11 mm. in diameter), there are six coronal plates, of which the uppermost has a well-formed tubercle and the other five carry primary spines, that on the second plate being the longest. As the animal grows, additional plates form abactinally but these have no primary tubercles and often scarcely an areola, while the spineless tubercle on the plate above the longest spine appears to be gradually more or less resorbed. In large specimens there are usually eight, and may be as many as nine, coronal plates, of which the five or six nearest the actinostome carry primaries, while the remaining two or three have no tubercles and only indications of small areolae. As the actinal coronal plates are small and crowded while those on the abactinal surface are very large, the spines are all actinal in position, except the longest which are just at the ambitus. Consequently the abactinal surface is extraordinarily bare, and the genus Anomocidaris is therefore easily recognized. — The primary spines are more slender than in Stereocidaris but show considerable diversity. They frequently taper to the very tip but are often more or less flaring there, and occasionally, in large specimens, are distinctly flattened and slightly widened at the extremity. They are grayish or brownish in color, often with a decidedly olive-green, very rarely a rosy-red, cast; the neck is brown, usually polished and shining, while the narrow collar is commonly dirty whitish, but may be darker than the neck. The primaries around the actinostome show the greatest diversity. In the smallest specimens, they are white, flat, curved at the tip, and distinctly serrate, exactly as Döderlein figures them for *japonica*, but in the large specimens they are dull gray, but little flattened, not at all curved, and with no trace of serrations. Intermediate conditions between the two extremes are common, and the differences appear to be due to age. — The pedicellariae are equally variable, for on some specimens, the large globiferous, such as Döderlein figures for *japonica*, are very common, on others they are rare and on others they seem to be wholly wanting. The diversity of the small globiferous pedicellariae has already been shown by us in "Hawaiian and Pacific Echini: Cidaridae," Plate 11, figs. 6–12 and Plate 12, fig. 18. They intergrade with the large globiferous pedicellariae quite imperceptibly. Tridentate pedicellariae appear to be always absent. — The color of the test and small spines also reveals some diversity. The test is commonly reddish-brown, but it may be greenish or not infrequently dirty whitish; it is almost always darkest abactinally. The small spines are usually distinctly greenish, more or less decidedly lighter on the edges than at the middle, but they may be

simply dirty whitish or have a reddish cast; they are decidedly brightest on the bare abactinal surface, where they are noticeably small but fairly abundant.

Station 4807. Between Hakodate and Sado Island, Japan, 44–47 fathoms.
" 4808. Between Hakodate and Sado Island, Japan, 47 fathoms.
" 4815. Between Hakodate and Sado Island, Japan, 70 fathoms.
" 4817. Between Hakodate and Sado Island, Japan, 61 fathoms.
" 4832. Between Nanao and Tsuruga, Hondo, Japan, 76–79 fathoms.
" 4833. Between Nanao and Tsuruga, Hondo, Japan, 79 fathoms.
" 4842. Between Dogo Island and Matsu Shima, Japan, 82 fathoms.
" 4876. Eastern Channel, Korea Strait, 59 fathoms.
" 5092. Uraga Strait, Gulf of Tokyo, 70 fathoms.
" 5094. Uraga Strait, Gulf of Tokyo, 88 fathoms.

Forty-nine specimens.

Goniocidaris biserialis Död.

Stephanocidaris biserialis Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 79.
Goniocidaris biserialis Döderlein, 1887. Jap. Seeigel, p. 10. Taf. 5; Taf. 8, fig. 8.

A very good series of this species was taken, ranging in size from 7 to 27 mm. The color shows considerable diversity, as the test and small spines may be yellow, olive-green, brown, or brownish-red. The primaries are uniformly dull, but they are more or less encrusted with sponges, bryozoans, worm-tubes, etc., and the color is thus often considerably modified.

Station 4875. Eastern channel, Korea Strait, 59 fathoms.
" 4876. Eastern channel, Korea Strait, 59 fathoms.
" 4877. Eastern channel, Korea Strait, 59 fathoms.
" 4879. Eastern channel, Korea Strait, 59 fathoms.
" 4893. Southwest of Goto Islands, Japan, 95–106 fathoms.
" 4894. Southwest of Goto Islands, Japan, 95 fathoms.
" 4895. Southwest of Goto Islands, Japan, 95 fathoms.
" 4936. Off Kagoshima Gulf, Japan, 103 fathoms.

Thirty-six specimens.

Goniocidaris clypeata Död.

Goniocidaris clypeata Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 82.

A good series of this curious species, ranging from 7 to 20 mm. in diameter, was taken, some of which are remarkably like some specimens of *florigera*. There seem to be, however, constant differences between the two species. The remarkable diversity revealed by the primary spines of these specimens is noteworthy, for some are tapering, only slightly thorny, and not at all expanded at either base or tip (young spines may even be perfectly smooth and tapering), while others, more or less conspicuously prickly, are expanded either at the base or at the tip or at both, and all kinds of intermediate types occur. The color of the test is usually reddish-brown, but may be much lighter. The secondary spines are light brownish. The primaries are gray

or whitish or even bright rose-red. The tuberculation of the median ambulacral area varies greatly; for, while in most specimens,each plate carries two or three small tubercles in addition to the large marginal one, so that the appearance of the area is much like that of *florigera*, in other specimens the middle of each ambulacrum is more or less sunken and bare as in *tubaria;* the two extremes, however, intergrade very evidently.

Station 4891. Southwest of Goto Islands, Japan, 181 fathoms.
" 4900. Southwest of Goto Islands, Japan, 139 fathoms.
" 4933. Off Kagoshima Gulf, Japan, 152 fathoms.
" 5091. Uraga Strait, Gulf of Tokyo, 197 fathoms.
" 5094. Uraga Strait, Gulf of Tokyo, 88 fathoms.

Nine specimens.

Goniocidaris mikado Död.

Discocidaris (*Cidaris*) *mikado* Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 80.
Goniocidaris mikado Döderlein, 1887. Jap. Seeigel, p. 15, Taf. 7; Taf. 8, figs. 6, 9-18.

A small series of this species is in the collection, ranging from 8 to 21 mm. in diameter. Specimens at any age are readily recognized by the remarkable, very small, nearly spherical miliary spines. The color, very light fawn, nearly cream-white, shows little variety.

Station 4893. Southwest of Goto Islands, 95–106 fathoms.
" 4894. Southwest of Goto Islands, 95 fathoms.
" 4895. Southwest of Goto Islands, 95 fathoms.
" 5070. Suruga Gulf, Japan, 108 fathoms.

Nine specimens.

Aporocidaris fragilis A. Ag. and Cl.

Aporocidaris fragilis A. Agassiz and Clark, 1907. Haw. Pacif. Ech. Cid., p. 37, Pl. 10, figs. 10–21; Pl. 23, figs. 5–8.

There is an excellent series of this species now available, ranging from 8 to 23 mm. in diameter, but there is little to add to our original description. The differences between *fragilis* and *Milleri* appear to be constant, and little diversity is shown. The color of these specimens differs from that of the type in being reddish-rather than yellowish-brown; it is considerably darker than in *Milleri.*

Station 4761. South of Shumagin Islands, Alaska, 1973 fathoms.

Twenty-five specimens.

SALENIDAE Agassiz.

Salenia miliaris A. Ag.

Salenia miliaris A. Agassiz, 1898. Bull. M. C. Z, **32**, p. 74, Pl. 2, figs. 2–4.

Two large specimens, about 17 mm. in diameter, are the only representatives of this species in the collection.

Station 5084. Off Omai Saki Light, Japan, 918 fathoms.

Two specimens.

Salenia cincta A. Ag. and Clark.

This handsome species is closely related to *Pattersoni* A. Ag., but is easily distinguished by the coloration. The test and secondaries, and especially the abactinal system, are deep purple or greenish more or less tinged with purple. The primaries are white, more or less distinctly shaded with green on the upper side, with 12 to 16 broad rings of dull red. The sculpturing of the abactinal system is quite different from that of *Pattersoni*, and tridentate pedicellariae seem to be wanting. The largest specimen is 12 mm. in diameter, and the longest primaries measure 52 mm. The latter are very slender, scarcely a millimeter in diameter, and are distinctly verticillate, though nearly smooth.

Station 4893. Southwest of Goto Islands, Japan, 95–103 fathoms.
" 4894. Southwest of Goto Islands, Japan, 95 fathoms.
" 4895. Southwest of Goto Islands, Japan, 95 fathoms.
" 4934. Off Kagoshima Gulf, Japan, 103–152 fathoms.
" 4936. Off Kagoshima Gulf, Japan, 103 fathoms.

Twelve specimens.

ARBACIADAE Gray.

Coelopleurus maculatus A. Ag. and Clark.

The specimens of Coelopleurus in the collection show no diversity in color or other features, and are strikingly handsome, with polished green primary spines conspicuously spotted on the upper side with scarlet red. The lower side is white, with somewhat indistinct red markings, as though the spots on the upper side showed through. Towards the tip of the spine, on the upper side, the red spots become confluent, so that the distal part of the spine is red for a greater or less distance, though it may be tipped with green or white. The primary spines are sharply triangular, especially near the base, and are distinctly curved towards the tip. The collar is short, rarely over five millimeters in length, dull and usually rough with four or five longitudinal series of coarse granules, on each side. The small actinal primary spines are flat and smooth, pure white, with very conspicuous gray collars extending half their length. — These specimens agree perfectly with the specimens taken by the "Challenger" at Amboina, and with others in the Museum collection from Uraga Channel, Japan, hitherto referred to *C. Maillardi*. It seems to be necessary, however, to distinguish them from that species, for in the type specimen of *Maillardi* from Bourbon, the primary spines are marked with deep purple and the collar is 8 mm. in length, and very finely and uniformly granular. Moreover, the secondary spines in *maculatus* are stout and blunt, rarely having a sharp point, while in *Maillardi* they are strikingly acicular. The largest specimen of *maculatus* before us measures 37 mm. in diameter; the primaries are all broken, but in other specimens they are three or four times the diameter of the test.

Station 4881. Eastern channel, Korea Strait, 40–59 fathoms.
" 4937. Off Kagoshima Gulf, Japan, 58 fathoms.

Five specimens.

ASPIDODIADEMATIDAE Duncan.

Aspidodiadema tonsum A. Ag.

Aspidodiadema tonsum, A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 199.

The specimens taken agree more nearly with the Aspidodiademas taken by the "Challenger" off Cebu, than with those (*nicobaricum*) in our Hawaiian collection.

Station 4980. Between Kobe and Yokohama, Japan, 507 fathoms.
" 5078. Off Omai Saki Light, Japan, 475–514 fathoms.
" 5079. Off Omai Saki Light, Japan, 475–505 fathoms.
" 5080. Off Omai Saki Light, Japan, 505 fathoms.

Fifteen specimens.

ECHINOTHURIDAE Wyville Thomson.

Asthenosoma pellucidum A. Ag.

Asthenosoma pellucidum A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 200.

The specimens are all small, less than 50 mm. in diameter, and their color is darker than that of "Challenger" specimens, but otherwise they are not peculiar.

Station 4934. Off Kagoshima Gulf, Japan, 103–152 fathoms.

Three specimens.

Asthenosoma Owstoni A. Ag. and Clark.

Araeosoma Owstoni Mortensen, 1904. Ann. Mag. Nat. Hist., (7) **14**, p. 82, Pl. 2, Pl. 5, figs. 4–9, 11, 18–20.

The specimens before us range in size from 20 to 150 mm., and agree well in all particulars with Mortensen's description, though they show a greater diversity in color. They vary from almost white (the smallest specimens) to nearly brick-red, but the largest specimens are dull, pale purplish. The actinal primary spines are decidedly pinkish, while those on the abactinal surface show only a very slight greenish tinge. The pedicellariae agree entirely with Mortensen's figures.

Station 4875. Eastern channel, Korea Strait, 59 fathoms.
" 4876. Eastern channel, Korea Strait, 59 fathoms.
" 4877. Eastern channel, Korea Strait, 59 fathoms.
" 4946. Between Kagoshima and Kobe, Japan, 39 fathoms.
" 5095. In Uraga Straits, Gulf of Tokyo, 58 fathoms.

Ten specimens.

Asthenosoma tessellatum A. Ag.

Asthenosoma tessellata A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 201.

The single specimen, 140 mm. in diameter, is somewhat damaged, but agrees very well with the "Challenger" specimen, which was taken near Manila.

Station 4943. In Kagoshima Gulf, Japan, 119 fathoms.

One specimen.

Asthenosoma bicolor A. Ag. and Clark.

This species is apparently nearly related to *Owstoni*, but differs in color and in certain features of the test. The coronal plates are low and very numerous, 44 in the interambulacra and 75 in the ambulacra; in *Owstoni* of the same size (125 mm.), the numbers are 38 and 60 respectively. The test is more flexible abactinally than in *Owstoni*, and the bare median ambulacral and interambulacral areas are more marked. The test and spines are dull yellowish actinally, while on the abactinal surface the interambulacra are chiefly yellow and the ambulacra are dull violet. These colors are not sharply defined, but contrast with each other nevertheless. The genital plates in *bicolor* are not so elongated as in *Owstoni*, for they separate only the first pair of interambulacral plates and touch the second, while in *Owstoni* they separate the first two pairs and touch, sometimes nearly separating, the third. In *bicolor*, four of the genitals are remarkable in that the outer part of the plate (*i. e.*, the part distal to the pore) is separated by a regular suture from the remainder of the genital, and thus is a perfectly distinct plate. The pedicellariae of *bicolor* appear to be identical with those of *Owstoni*.

Station 4939. In Kagoshima Gulf, Japan, 85 fathoms.

One specimen.

Asthenosoma pyrochloa A. Ag. and Clark.

This handsome species is very nearly related to the Atlantic species *hystrix*, and is only to be distinguished by the color and some differences in the arrangement of the primary tubercles. The entire test is of a most brilliant vermilion-red, strikingly different from the rich rose-red of *hystrix*. In the ambulacra, on the actinal side, there are two distinct vertical series of tubercles, beginning near the peristome and running nearly or quite to the ambitus. These series lie near together in the median ambulacral area, and on the outer side of each is a shorter and less complete series. In the interambulacra we find very regular series running along the margins close to the ambulacra, and in each area there is a second series on the inner ends of the interambulacral plates. Each plate also carries, not infrequently, one or two additional tubercles. Abactinally each interambulacral plate carries two and often three large tubercles. The secondary and miliary spines are much coarser, and possibly more numerous, than in *hystrix*, so that the general appearance, especially of the abactinal surface, is rather different. The largest specimen is about 190 mm. in diameter.

Station 4919. Off Kagoshima Gulf, Japan, 440 fathoms.
" 5083. Off Omai Saki Light, Japan, 624 fathoms.

Three specimens.

Phormosoma bursarium A. Ag.

Phormosoma bursarium A. Agassiz, 1881. Rept. Chall. Ech., p. 99, Pl. 10 b.

Although these specimens from the northwestern Pacific show such diversity among themselves that they can be divided into two groups, and although neither of

these groups is wholly like the Hawaiian Island form, collected by the "Albatross" in 1902, nevertheless it does not seem to be practicable to distinguish more than a single species. A large proportion of the present collection is made up of young specimens, under 30 mm. in diameter, but the individuals range from 20 to 110 mm.

Station 4906. Southwest of Koshika Islands, Japan, 369–406 fathoms
" 4907. Southwest of Koshika Islands, Japan, 406 fathoms.
" 4911. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4912. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4913. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4914. Southwest of Koshika Islands, Japan, 427 fathoms.
" 4915. Southwest of Koshika Islands, Japan, 427 fathoms.
" 4957. Between Kagoshima and Kobe, Japan, 437 fathoms.
" 4968. Between Kobe and Yokohama, Japan, 253 fathoms.
" 4969. Between Kobe and Yokohama, Japan, 587 fathoms.
" 5078. Off Omai Saki Light, Japan, 475–514 fathoms.
" 5082. Off Omai Saki Light, Japan, 662 fathoms.
" 5084. Off Omai Saki Light, Japan, 918 fathoms.
" 5086. Sagami Bay, Hondo, Japan, 292 fathoms.
" 5088. Sagami Bay, Hondo, Japan, 369–405 fathoms.

Thirty specimens.

Phormosoma hoplacantha Wyv. Thoms.

Phormosoma hoplacantha Wyville Thomson, 1877. Voy. Chall. Atlantic, **1**, p. 148, fig. 35.

A fairly good series of a Phormosoma, which seems to be identical with the "Challenger" specimens of *hoplacantha*, was taken at the following stations.

Station 4928. In Colnett Strait, Japan, 1008 fathoms.
" 4956. Between Kagoshima and Kobe, Japan, 720 fathoms.
" 4958. Between Kagoshima and Kobe, Japan, 405 fathoms.
" 4973. Between Kobe and Yokohama, Japan, 600 fathoms.
" 4980. Between Kobe and Yokohama, Japan, 507 fathoms.
" 5078. Off Omai Saki Light, Japan, 475–514 fathoms.
" 5080. Off Omai Saki Light, Japan, 505 fathoms.
" 5082. Off Omai Saki Light, Japan, 662 fathoms.
" 5084. Off Omai Saki Light, Japan, 918 fathoms.
" 5086. Sagami Bay, Hondo, Japan, 292 fathoms.

Thirteen specimens.

Phormosoma tenue A. Ag.

Phormosoma tenuis A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 202.

The specimens referred to this species are of interest from having ophicephalous pedicellariae in addition to the characteristic tridentate ones. As Döderlein (**1906**,

Valdivia Echini, p. 121), has suggested, ophicephalous pedicellariae probably occur in most if not all of the genera proposed by Mortensen. Those of *tenue* are very similar to those figured by D derlein for *Sperosoma durum*. — The color of the "Albatross" specimens is violet above, becoming deep reddish-purple actinally, while the "Challenger" specimens were "yellowish-gray," but in the general appearance and the arrangement of the tubercles there seem to be no important differences between the two series.

Station 4928. In Colnett Strait, Japan, 1008 fathoms.
" 5084. Off Omai Saki Light, Japan, 918 fathoms.
Four specimens.

Sperosoma quincunciale DE MEIJ.

Sperosoma quincunciale de Meijere, 1904. Ech. Siboga-Exp., p. 40, Pl. 13, figs. 166–176.

A number of Echinothurids, closely resembling *P. tenue*, prove on careful examination to be Sperosomas, which we are unable to distinguish from *quincunciale*, though none of the specimens is as large as de Meijere's type. They range from 45 mm. to 170 mm. in diameter and are all more or less deep violet in color. The actinal primary spines are provided with large and conspicuous white "hoofs." The arrangement of the ambulacral pores abactinally is very characteristic.

Station 4957. Between Kagoshima and Kobe, Japan, 437 fathoms.
" 5079. Off Omai Saki, Japan, 475–505 fathoms.
" 5080. Off Omai Saki, Japan, 505 fathoms.
Eight specimens.

Sperosoma biseriatum DÖD.

Sperosoma biseriatum Döderlein, 1901. Zool. Anz., **23**, p. 20.

We refer to this species, but not without some hesitation, a badly mutilated specimen of Sperosoma, easily distinguished from the preceding by the arrangement of the ambulacral pores abactinally, which are just as Döderlein (**1906**, p. 152; Pl. 19, fig. 1) describes and figures them for *biseriatum*. The color and the pedicellariae show slight differences, however, for the test of this specimen was obviously deep purple, and the valves of the pedicellariae have a straight, smooth margin. It is quite possible that this specimen really represents an undescribed species.

Station 4766. Between Atka Island and Bowers Bank, Bering Sea, 1766 fathoms.
One specimen.

Sperosoma giganteum A. AG. and CLARK.

This remarkable Echinothurid measures nearly 320 mm. in its greatest horizontal diameter. The color is very deep purple, almost black when in shadow. The ambulacra are extraordinarily wide, for on the abactinal surface just above the ambitus they measure over 100 mm. while the interambulacra are little over 70. The outer and inner columns in each half of each ambulacrum are made up of re-

markably long, low plates, which just above the ambitus are 25 mm. long and only 5 mm. high. There are no primary tubercles above the ambitus but the whole abactinal surface is rather closely covered with slender secondaries and miliaries. On the actinal surface, primary spines are fairly numerous but show no regular arrangement. Many ambulacral plates have two, and many interambulacral plates four spines. The areolae are small, the diameter usually less than half the height of the plate. The primary spines are seldom 25 mm. long and terminate in a conspicuous white hoof; nearly all are, however, broken off. The pedicellariae are interesting, for in addition to tridentate pedicellariae, similar to those of *Sperosoma biseriatum* Död., but seldom with valves as much as two millimeters long, we find ophicephalous and triphyllous pedicellariae abundant. The latter are not peculiar but the former are almost exactly like those figured by Mortensen (**1903**, Pl. 14, fig. 23) as characteristic of his proposed new genus "Tromikosoma"! In no other respect, however, does this species resemble that group. Unfortunately only one specimen of this interesting Echinothurid was taken.

Station 5082. Off Omai Saki Light, Japan, 662 fathoms.

One specimen.

ECHINOMETRIDAE Gray.

Strongylocentrotus Dröbachiensis A. Ag.

Echinus Dröbachiensis O. F. Müller, 1776. Prod. Zool. Dan., p. 235.
Strongylocentrotus Dröbachiensis A. Agassiz, 1872. Rev. Ech., Pt. 1, p. 162.

A considerable number of specimens of Strongylocentrotus were collected along the North American coast from British Columbia northwestward, across the Pacific. They show little diversity among themselves and only very slight, if any, differences from specimens collected at Eastport, Maine. For the present at least they may be considered as *Dröbachiensis*.

Bayle Island, British Columbia.
Unalaska, Aleutian Islands.
Atka, Aleutian Islands.
Agattu, Aleutian Islands.
Medni, Komandorski Islands.
Bering, Komandorski Islands.
Petropaulovsk, Siberia.
Forty-three specimens.

Strongylocentrotus nudus A. Ag.

Toxocidaris nuda A. Agassiz, 1863. Proc. Acad. Nat. Sci., Phila., p. 356.
Strongylocentrotus nudus A. Agassiz, 1872. Rev. Ech., Pt. 1, p. 165.

A single immature specimen, only 23 mm. in diameter, seems to be the young of this species, for the arcs of 6 or 7 pairs of pores are nearly vertical and the poriferous zones are correspondingly narrow. The primary tubercles are conspicuous while the other tubercles are few in number and small. The abactinal ambu-

lacral plates show radiating lines on the outer half, corresponding in number to the pairs of pores, as in larger specimens of *nudus*. The test is dull purplish with an evident greenish cast abactinally, and the primary spines and secondaries are more or less greenish. The color is thus quite unlike that of adult *nudus*.

Station 5018. Off Cape Tonin, Saghalin Island, 100 fathoms.

One specimen.

Strongylocentrotus tuberculatus Br.

Echinus tuberculatus Lamarck, 1816. Anim. s. Vert., **3**, p. 50.

Strongylocentrotus tuberculatus Brandt, 1835. Prod. Desc. Anim., p. 264.

The specimens are all (except one) large and of a very deep reddish-purple color. Hakodate.

Station 4807. Between Hakodate and Sado Island, Japan, 44–47 fathoms.

Six specimens.

Strongylocentrotus echinoides A. Ag. and Clark.

It is hard to believe that a littoral Echinoid as common as this species seems to be, and as conspicuous, is still undescribed, but we are entirely at a loss in the attempt to assign it to any known species. The specimens range from 10 to 72 mm. in diameter. The general appearance and coloration in most of the adults, are quite like an Echinus, but the arrangement of the pores, in arcs of seven pairs (six in small specimens) is like Strongylocentrotus, and the pedicellariae of all four kinds are scarcely distinguishable from those of *Dröbachiensis*. The height of the test varies greatly, ranging from .45 of the diameter to .55. The color is equally variable but the test is more or less reddish-white, darkest on the abactinal median interambulacral areas which may be even deep reddish-purple. The small spines are light greenish, but the primaries show considerable diversity. They are commonly dull reddish at the base, becoming very light greenish at the tip, but in some cases, they are wholly green and in others, wholly light red. They are rather long (10–15 mm.), slender and pointed, but not at all numerous. In each interambulacrum, there are two vertical series of 12–20 large tubercles, each of which is flanked on each side by a less regular row of much smaller tubercles. In each ambulacrum, the median area is bounded on each side by a series of 18–30 tubercles, slightly smaller than the largest of those in the interambulacra, and between these two series are two less complete rows of much smaller tubercles. The secondary and miliary spines are very numerous, but are much shorter than the primaries. The abactinal system is small (about .20 of the diameter) and the two posterior ocular plates are in broad contact with the anal system. Pedicellariae, particularly the globiferous ones, are very numerous, and the tridentate are often two millimeters long, not including the stalk.

Station 4777. Petrel Bank, Bering Sea, 43–52 fathoms.
" 4778. Petrel Bank, Bering Sea, 33–43 fathoms.
" 4779. Petrel Bank, Bering Sea, 54–56 fathoms.
" 4782. Off East Cape, Attu Island, Aleutians, 57–59 fathoms.
" 4784. Off East Cape, Attu Island, Aleutians, 135 fathoms.

Station 4786. Between Medni and Bering, Komandorski Islands, 54 fathoms.
" 4787. Between Medni and Bering, Komandorski Islands, 54–57 fathoms.
" 4788. Between Medni and Bering, Komandorski Islands, 56–57 fathoms.
" 4789. Between Medni and Bering, Komandorski Islands, 56 fathoms.
" 4790. Between Medni and Bering, Komandorski Islands, 64 fathoms.
" 4791. Between Medni and Bering, Komandorski Islands, 72–76 fathoms.
" 4792. Between Medni and Bering, Komandorski Islands, 72 fathoms.
" 4794. Off east coast of Kamchatka, 58–69 fathoms.
" 4795. Off east coast of Kamchatka, 48–69 fathoms.
" 4796. Off east coast of Kamchatka, 48 fathoms.
" 4804. Off Simushir Island, 229 fathoms.
" 4810. Between Hakodate and Sado Island, Japan, 90-195 fathoms.
" 4822. Between Nanao and Tsuruga, Hondo, Japan, 130 fathoms.
" 4982. Between Hakodate and Otaru, Hokkaido, Japan, 390–428 fathoms.
" 4987. Between Hakodate and Otaru, Hokkaido, Japan, 59 fathoms.
" 4993. Between Otaru, Hokkaido, and Korsakov, Saghalin, 142 fathoms.
" 4996. Between Otaru, Hokkaido, and Korsakov, Saghaliu, 86 fathoms.
" 5016. Off eastern coast, southern end of Saghalin, 64 fathoms.
" 5041. Off southern coast of Hokkaido, Japan, 61–140 fathoms.
" 5048. Between Hakodate and Yokohama, Japan, 129 fathoms.
" 5049. Between Hakodate and Yokohama, Japan, 182 fathoms.

One hundred and sixty-two specimens.

Strongylocentrotus polyacanthus A. Ag. and Clark.

While the specimen to which we have given this name may prove to be an aberrant example of either *Dröbachiensis* or *purpuratus*, it seems best to recognize it now as a distinct species. It may be distinguished by the very numerous short spines, the primaries little exceeding the secondaries in either length (6–8 mm.) or thickness; the numerous (25) coronal plates; and the color. The test is 73 mm. in diameter and both it and the spines are dull rose-purple. The pairs of pores are in oblique, but little curved, arcs of six. Each coronal plate at the ambitus carries 3–5 primary, 25–35 secondary, and 50–60 miliary tubercles.

Milne Bay, Simushir Island, Kuril Islands, Japan.

One specimen.

Strongylocentrotus pulchellus A. Ag. and Clark.

Although the genital pores are large, it is doubtful whether even the larger of our two specimens is adult, as it is only 17 mm. in diameter. But there can be

little question that they represent an undescribed species, for the arrangement of the pores is very characteristic. The pairs are in very oblique, somewhat curved arcs of five, divided by a secondary tubercle into an inner group of two, and an outer, lower group of three pairs. The vertical series of secondary tubercles thus divides the poriferous zone into an inner and an outer band, the latter somewhat the wider. The globiferous pedicellariae are also very unique, for the expanded basal part of each valve is very wide, .60 of the length of the valve, and the terminal tooth is very long, .25–.35 of the valve length. Tridendate pedicellariae appear to be wanting. The test is very light purplish, noticeably darker abactinally, particularly on the median interambulacral areas; on and around the abactinal system there is a very evident green tinge. The primary spines are light purple, rather abruptly tipped with whitish. The smaller spines are very much lighter. In the smaller specimen (9 mm.), the primary spines are purplish only at base, the terminal part being light greenish and the arcs of pore-pairs are nearly vertical above the ambitus and are uninterrupted.

Station 4794. Off east coast of Kamchatka, 58–69 fathoms.
" 5003. Off southwestern coast of Saghalin Island, 35–38 fathoms.

Two specimens.

TEMNOPLEURIDAE Desor.

Temnopleurus Reynaudi Agass.

Temnopleurus Reynaudi Agassiz, 1846. Ann. Sci. Nat., **6**, p. 360.

The specimens taken by the "Albatross" are all small (9–23 mm.) and show no little diversity. The test is thin and the spines are long and slender. The depth of the pits varies greatly in different specimens, in some cases being so shallow as to be scarcely noticeable. The proportion of height to diameter is also variable, ranging from 40 to 55 per cent. The color of the test varies from dull purple, lighter on the poriferous zones, to yellowish-white, blotched around the abactinal system with red, green, purplish, or brown. The spines are brownish, purplish, greenish or dirty white, sometimes much lighter at base than at tip.

Station 4815. Between Hakodate and Sado Island, Japan, 70 fathoms.
" 4832. Between Nanao and Tsuruga, Hondo, Japan, 76–79 fathoms.
" 4893. Southwest of Goto Islands, Japan, 95–106 fathoms.
" 4894. Southwest of Goto Islands, Japan, 95 fathoms.
" 4895. Southwest of Goto Islands, Japan, 95 fathoms.
" 4902. Southwest of Goto Islands, Japan, 139 fathoms.
" 4904. Southwest of Goto Islands, Japan, 107 fathoms.
" 4931. In Colnett Strait, Japan, 83 fathoms.
" 4933. Off Kagoshima Gulf, Japan, 152 fathoms.
" 5074. In Suruga Gulf, Japan, 47 fathoms.
" 5095. Off Gulf of Tokyo, Japan, 58 fathoms.

Seventeen specimens.

Temnopleurus toreumaticus Agass.

Cidaris toreumatica Klein, 1734. Nat. Disp. Ech., p. 22, Pl. 10, fig. E.
Temnopleurus toreumaticus Agassiz, 1841. Mon. d'Ech., Obs., p. 7.

There is only a single specimen of this well-known species, taken at Nanao Beach, Japan.

Salmacopsis olivacea Död.

Salmacopsis olivacea Döderlein, 1885. Arch. f. Naturg., Jahrg., **51**, Bd. 1, p. 93.

These specimens differ from Döderlein's in their larger size and decidedly greener color. The largest are over 25 mm. in diameter.

Station 4894. Southwest of Goto Islands, Japan, 95 fathoms.
" 4937. In Kagoshima Gulf, Japan, 58 fathoms.
Five specimens.

Pleurechinus variabilis Död.

Pleurechinus variabilis Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 90.

The specimens are small (8–11 mm.) and show little diversity.

Station 4893. Southwest of Goto Islands, Japan, 95–106 fathoms.
" 4894. Southwest of Goto Islands, Japan, 95 fathoms.
" 5068. In Suruga Gulf, Japan, 77–131 fathoms.
Three specimens.

Pleurechinus variegatus Mort.

Pleurechinus variegatus Mortensen, 1904. Dan. Exp. Siam: Ech., p. 84; Pl. 1, figs. 5, 6, 8, 19; Pl. 2, fig. 6.

This species is not readily distinguished from the preceding one unless at least a part of an interambulacrum is cleaned, yet the banding of the primaries, and the usual absence at their tips of a terminal thorn, are features of *variegatus* recognizable with a good lens. The specimens before us have scarcely a trace of red on the primaries, but they are not otherwise peculiar.

Station 4893. Southwest of Goto Islands, Japan, 95–106 fathoms.
" 4895. Southwest of Goto Islands, Japan, 95 fathoms.
" 5095. Off Gulf of Tokyo, Japan, 58 fathoms.
Three specimens.

Prionechinus Agassizii Wood-Mas. and Alc.

Prionechinus Agassizii Wood-Mason and Alcock, 1891. Ann. Mag. Nat. Hist., (6) **8**, p. 441.

Our specimens agree so well with the description and figures of Döderlein (**1906**, p. 194; Pl. 24, fig. 1; Pl. 35, fig. 7) that there can be little question of their identity with his specimen. They show striking diversity in color, however, for while one is pure white, a second has the test pale brown and the very base of the spines tinged with olive, and the third has the tubercles and the basal half of all the larger spines pale red.

Station 4965. Between Kobe and Yokohama, Japan, 191 fathoms.
" 4967. Between Kobe and Yokohama, Japan, 244–253 fathoms.
" 5086. Sagami Bay, Hondo, Japan, 292 fathoms.
Three specimens.

Prionechinus ruber A. Ag. and Clark.

This species may be recognized by the following combination of characters. The test and abactinal system show little evidence of sculpturing; the anal system is covered by ten to twenty plates, of which one is somewhat larger than the others; there are ten large buccal plates, each with a well developed tube-foot, and between these plates and the mouth the membrane is closely covered with small plates; the primary spines are nearly or quite smooth and rather sharply pointed; the test and basal half of the larger spines are red, while the tips of the spines and some of the tubercles are pure white. The larger specimen is 11 mm. in diameter.
Station 4933. Off Kagoshima Gulf, Japan, 152 fathoms.
" 4967. Between Kobe and Yokohama, Japan, 244–253 fathoms.
Two specimens.

Genocidaris apodus A. Ag. and Clark.

This interesting species is easily recognized by the very large anal plate, the long primary spines which when unbroken exceed the diameter of the test, and the presence of only five large buccal plates, provided with a tube-foot. The second plate of each pair is rudimentary and carries no pedicel. There are no other plates on the buccal membrane. The test is very distinctly sculptured, but the abactinal system is nearly smooth and carries very few (15–25) small tubercles. The genital pores are large, in the centre of a slight elevation. The abactinal system is very large, its diameter sixty per cent or more of that of the test. The test and spines are white, but in the smallest specimen (the only one with unbroken spines) the terminal half of the longer primaries is red. The largest specimen is only 7 mm. in diameter.
Station 4891. Southwest of Goto Islands, Japan, 181 fathoms.
" 4904. Southwest of Goto Islands, Japan, 107 fathoms.
Three specimens.

TRIPLECHINIDAE A. Ag.

Hemipedina mirabilis Död.

Hemipedina mirabilis Döderlein, 1885. Arch. f. Naturg., Jahrg., **51**, Bd. 1, p. 96.

The excellent series of specimens now before us confirms our recently expressed opinion (Bull. M. C. Z., 50, p. 245) that this species is quite distinct from *H. indica* de Meij.

Station 4807. Between Hakodate and Sado Island, Japan, 44–47 fathoms.
" 4808. Between Hakodate and Sado Island, Japan, 47 fathoms.
" 4900. Southwest of Goto Islands, Japan, 139 fathoms.
" 4933. Off Kagoshima Gulf, Japan, 152 fathoms.
" 4934. Off Kagoshima Gulf, Japan, 103–152 fathoms.
" 4965. Between Kobe and Yokohama, Japan, 191 fathoms.
" 5047. Between Hakodate and Yokohama, Japan, 107 fathoms.

Thirty-seven specimens.

Phymosoma crenulare A. Ag.

Glyptocidaris crenularis A. Agassiz, 1863. Proc. Acad. Nat. Sci. Phila., p. 356.
Phymosoma crenulare A. Agassiz, 1872. Rev. Ech., Pt. I, p. 151.

The "Albatross" collected a single very fine specimen, 77 mm. in diameter, with the longest spines measuring about 55 mm., and three other much smaller specimens.

Station 4807. Between Hakodate and Sado Island, Japan, 44–47 fathoms.
" 5046. Between Hakodate and Yokohama, Japan, 82 fathoms.

Four specimens.

Echinus lucidus Död.

Echinus lucidus Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 97.

An excellent series of this species shows great diversity in the height of the test and in the length of the primary spines.

Station 4917. Off Kagoshima Gulf, Japan, 361 fathoms.
" 4957. Between Kagoshima and Kobe, Japan, 437 fathoms.
" 4958. Between Kagoshima and Kobe, Japan, 405 fathoms.
" 4959. Between Kagoshima and Kobe, Japan, 405–578 fathoms.
" 4965. Between Kobe and Yokohama, Japan, 191 fathoms.
" 4980. Between Kobe and Yokohama, Japan, 507 fathoms.
" 5048. Between Hakodate and Yokohama, Japan, 129 fathoms.
" 5049. Between Hakodate and Yokohama, Japan, 182 fathoms.
" 5051. Between Hakodate and Yokohama, Japan, 399 fathoms.
" 5078. Off Omai Saki Light, Japan, 475–514 fathoms.
" 5079. Off Omai Saki Light, Japan, 475–505 fathoms.
" 5082. Off Omai Saki Light, Japan, 662 fathoms.
" 5083. Off Omai Saki Light, Japan, 624 fathoms.
" 5084. Off Omai Saki Light, Japan, 918 fathoms.
" 5088. Sagami Bay, Japan, 369–405 fathoms.

Fifty-six specimens.

CLYPEASTRIDAE Agassiz.

ECHINANTHIDAE A. Agassiz.

Clypeaster virescens Död.

Clypeaster virescens Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 102.

The species of Clypeaster in this collection seem to represent but a single species (except possibly one of the very young ones), and we refer them with little doubt to this form, which Döderlein found not uncommon in Sagami Bay. They range from 14 to 114 mm. in length, and the largest is 108 mm. wide and 24 mm. high.

Station 4877. Eastern channel, Korea Strait, 59 fathoms.
" 4884. Between Nagasaki and Kagoshima, Japan, 53 fathoms.
" 4885. Between Nagasaki and Kagoshima, Japan, 53 fathoms.
" 4893. Southwest of Goto Islands, Japan, 95–106 fathoms.
" 4894. Southwest of Goto Islands, Japan, 95 fathoms.
" 4895. Southwest of Goto Islands, Japan, 95 fathoms.
" 4937. Kagoshima Gulf, Japan, 58 fathoms.
" 4948. Between Kagoshima and Kobe, Japan, 65 fathoms.
" 5071. In Suruga Gulf, Japan, 57 fathoms.
" 5095. Gulf of Tokyo, Japan, 58 fathoms.

Fourteen specimens.

LAGANIDAE Desor. (Emended.)

Laganum fudsiyama Död.

Laganum fudsiyama Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 104.

A number of large Laganidae are apparently the adults of this species. They range from 50 to 71 mm. in long diameter.

Station 4965. Between Kobe and Yokohama, Japan, 191 fathoms.
" 4966. Between Kobe and Yokohama, Japan, 244–290 fathoms.
" 4967. Between Kobe and Yokohama, Japan, 244–253 fathoms.
" 5091. Off Gulf of Tokyo, Japan, 197 fathoms.

Thirty-one specimens.

Laganum pellucidum Död.

Peronella (Laganum) pellucida Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 104.

Although the specimens available are bare tests, there can be no mistaking this easily recognized species.

Station 4885. Between Nagasaki and Kagoshima, Japan, 53 fathoms.

Two specimens.

Laganum diploporum A. Ag. and Clark.

This interesting species resembles *strigatum* A. Ag. and Cl. in the form of the test and the shape of the petals. But the sutures between the plates are scarcely visible, and the color is commonly light green, often yellowish, sometimes brownish. The striking characteristic, however, is the presence of *six* genital pores, two of which are in the posterior interambulacrum. Of the 54 specimens with an uninjured abactinal system, 34 show the *six* pores plainly; of the remaining 20, 17 are under 20 mm. in length, and most of them have no genital pores, at least in the posterior interambulacrum. One specimen, 22 mm. long, has five small pores, but the one in the posterior interambulacrum is at the extreme right hand side of that area. A specimen 37 mm. long, and another 43 mm., apparently have only one pore in the posterior interambulacrum, but under the microscope it becomes evident that this pore is formed by the fusion of two. The steps in the history of such a fusion are all shown in the large series of specimens available. The great majority of the specimens are circular or nearly so, but some of the smaller ones are slightly elongated. The most elongated specimen measures 28 by 26 mm., while the largest ones are 38 × 38.5, 40 × 42, and 43 × 42. The smallest is only 8 mm. in diameter.

Station 4885. Between Nagasaki and Kagoshima, Japan, 53 fathoms.
" 4888. Between Nagasaki and Kagoshima, Japan, 71 fathoms.
" 4893. Southwest of Goto Islands, Japan, 95–106 fathoms.
" 4895. Southwest of Goto Islands, Japan, 95 fathoms.
" 4902. Southwest of Goto Islands, Japan, 139 fathoms.
" 4904. Southwest of Goto Islands, Japan, 107 fathoms.
" 4933. Off Kagoshima Gulf, Japan, 152 fathoms.
" 4934. Off Kagoshima Gulf, Japan, 103–152 fathoms.
" 4937. Off Kagoshima Gulf, Japan, 58 fathoms.
" 5055. Suruga Gulf, Japan, 124 fathoms.
" 5070. Suruga Gulf, Japan, 108 fathoms.
" 5092. Off Gulf of Tokyo, Japan, 70 fathoms.

Fifty-six specimens.

SCUTELLIDAE Agassiz.

Echinarachnius excentricus Val.

Scutella excentrica Eschscholtz, 1829. Zoöl. Atl., Pl. 20, fig. 2.

Echinarachnius excentricus Valenciennes, 1846. Voy. Venus. Zooph., Pl. 10.

There is a good series of twenty-four specimens of this curious species from Union Bay, Bayne Island, British Columbia.

Echinarachnius mirabilis A. Ag.

Scaphechinus mirabilis Barnard Mss., A. Agassiz, 1863. Proc. Acad. Nat. Sci., Phila., p. 359.

Echinarachnius mirabilis A. Agassiz, 1872. Rev. Ech., Pt. 1, p. 107.

There are numerous sand-dollars in the collection, which appear to belong to this species.

Station 4786. Between Medni and Bering, Komandorski Islands, 54 fathoms.
" 4787. Between Medni and Bering, Komandorski Islands, 54–57 fathoms.
" 4794. Off East Coast of Kamchatka, 58–69 fathoms.
" 4795. Off East Coast of Kamchatka, 48–69 fathoms.
" 4796. Off East Coast of Kamchatka, 48 fathoms.

Sixty specimens.

PETALOSTICHA Haeckel.

CASSIDULIDAE Agassiz.

NUCLEOLIDAE Agassiz.

Echinolampas sternopetala A. Ag. and Clark.

This species may be at once recognized by its narrow apetaloid ambulacra, with moderately long, straight, unequal poriferous zones. The color is bright yellowish-green. Length, 47 mm.; width, 40 mm.; height, 21 mm. Unpaired ambulacrum (poriferous portion), 12 mm. long, 2.5 mm. wide at open end, with 27 pairs of pores in left zone and 30 in right; right anterior ambulacrum, 15 × 2.5 mm., with 27 pairs of pores in left zone and 37 in right; right posterior ambulacrum, 15 × 2.5 mm., with 32 pairs of pores in left zone and only 25 in right. Anal system covered mainly by three large plates.

Station 4934. Off Kagoshima Gulf, Japan, 103–152 fathoms.

One specimen.

SPATANGIDAE Agassiz.

POURTALESIAE A. Agassiz.

Pourtalesia laguncula A. Ag.

Pourtalesia laguncula A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 205.

A good series of specimens, up to 30 mm. in length, is at hand. There is also a posterior fragment of a much larger individual, in which the anal snout is dorsally flattened and 10 mm. wide. This individual was apparently over 50 mm. long and possibly represents an undescribed species.

Station 4766. Between Atka Island and Bowers Bank, Bering Sea, 1766 fathoms.
" 4906. Southwest of Koshika Islands, Eastern Sea, 369–406 fathoms.
" 4911. Southwest of Koshika Islands, Eastern Sea, 391 fathoms.
" 4912. Southwest of Koshika Islands, Eastern Sea, 391 fathoms.
" 4913. Southwest of Koshika Islands, Eastern Sea, 391 fathoms.
" 4914. Southwest of Koshika Islands, Eastern Sea, 427 fathoms.
" 4915. Southwest of Koshika Islands, Eastern Sea, 427 fathoms.

Station 4968. Between Kobe and Yokohama, Japan, 253 fathoms.
" 5054. Suruga Gulf, Japan, 282 fathoms.
" 5055. Suruga Gulf, Japan, 124 fathoms.
" 5072. Suruga Gulf, Japan, 148–284 fathoms.
Fifty-six specimens.

URECHINIDAE Lambert. (Emended. A. Agassiz.)

Urechinus naresianus A. Ag.

Urechinus naresianus A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 207.

A series of Urechinus, ranging in length from 30 to 58 mm., does not seem to be distinguishable by any constant character from this cosmopolitan species.

Station 4766. Between Atka Island and Bowers Bank, Bering Sea, 1766 fathoms.
" 5030. 46° 29′ 30″ N. × 145° 46′ E., 1800 fathoms.
Thirteen specimens.

Cystechinus purpureus A. Ag. and Clark.

Although this species is nearly allied to the southern *Wyvillii*, it is distinguished from that species by the more compact abactinal system, having only three genital pores, much smaller and wholly inconspicuous pedicels, and the much deeper purple color, which has little or no tendency to red. The genital plates are more or less approximately square, and the distance from the anterior pore to either of the posterior ones is not much greater than from one of the latter to the other. The test is much lower and the individuals are all smaller than the full-grown *Wyvillii*. Although the tests vary considerably in relative height, the diversity is not so great as is shown in *Urechinus naresianus*, as figured in the "Challenger" Report (Plate XXX a) by A. Agassiz. The plates near the ambitus are very low, as in Urechinus, with which genus this species is an obvious connecting link. The largest specimen is 66 mm. long and 23 mm. high, while another not quite so long is 33 mm. high.

Station 4761. 53° 57′ 30″ N. × 159° 31′ W., 1973 fathoms.
" 4766. Between Atka Island and Bowers Bank, Bering Sea, 1766 fathoms.
" 5030. 46° 29′ 30″ N. × 145° 46′ E., 1800 fathoms.
Nine specimens.

PALAEOPNEUSTIDAE A. Agassiz.

Palaeopneustes fragilis de Meij.

Palaeopneustes fragilis de Meijere, 1903. Tijd. Ned. Dierk. Ver., (2) **8**, p. 12.

All of the specimens are large and badly broken, but there is no doubt of their identity with this East Indian species.

Station 4969. Between Kobe and Yokohama, Japan, 587 fathoms.
" 4970. Between Kobe and Yokohama, Japan, 500–649 fathoms.
" 5053. Suruga Gulf, Japan, 503 fathoms.
" 5080. Off Omai Saki Light, 505 fathoms.

Four specimens.

Linopneustes excentricus DE MEIJ.

Linopneustes excentricus de Meijere, 1903. Tijd. Ned. Dierk. Ver., (2) **8**, p. 13.

There is a good series of this Spatangoid, ranging from 24 to 84 mm. in long diameter.

Station 4906. Southwest of Koshika Islands, Japan, 369–406 fathoms.
" 4907. Southwest of Koshika Islands, Japan, 406 fathoms.
" 4909. Southwest of Koshika Islands, Japan, 434 fathoms.
" 4911. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4912. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4915. Southwest of Koshika Islands, Japan, 427 fathoms.

Eleven specimens and numerous fragments.

Meijerea excentrica A. AG. and CL.

Meijerea excentrica A. Agassiz and Clark, 1907. Bull. M. C. Z., **50**, p. 252.

One of the specimens is 100 mm. long, 80 mm. wide and 30 mm. high, and the abactinal system is 52 mm. from the anterior margin. The color of this specimen is a much deeper brown than that of smaller specimens and has a distinct reddish tinge.

Station 4908. Southwest of Koshika Islands, Japan, 434 fathoms.
" 4911. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4912. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4914. Southwest of Koshika Islands, Japan, 427 fathoms.
" 4956. Between Kagoshima and Kobe, Japan, 720 fathoms.

Two specimens and numerous fragments.

Meijerea plana A. AG. and CLARK.

At first glance, the individual on which this species is based, might be considered a young specimen of the preceding, but more careful examination makes this seem impossible. The test is 28 mm. long, 22 mm. wide, 4 mm. high at the anterior margin and 9 mm. high at the posterior end, where it is abruptly truncate. The anal system is on this vertical posterior surface. The abactinal system is excentric, 15 mm. from the anterior margin. The actinostome is little sunken and there is practically no labrum. The subanal fasciole is not at all angular and encloses a space 6 mm. wide by 2 mm. high. The shape of the test

and the absence of a conspicuous labrum easily distinguish this species from *excentrica* to which it is otherwise very nearly allied.

Station 4919. Off Kagoshima Gulf, Japan, 440 fathoms.

One specimen.

SPATANGINA Gray.

Spatangus Lütkeni A. Ag.

Spatangus Lütkeni A. Agassiz, 1872. Bull. M. C. Z. **3**, p. 57.

The specimens are well preserved but small.

Station 4807. Between Hakodate and Sado Island, Japan, 44–47 fathoms.

" 5047. Between Hakodate and Yokohama, Japan, 107 fathoms.

Six specimens.

Gymnopatagus magnus A. Ag. and Clark.

This fine new species is larger than any of the other members of the genus, our best specimen measuring 98 mm. long, 80 mm. wide, and 30 mm. high. It is much nearer to *valdiviae*, the type of the genus, in the form of the test and petals, than are either of the Hawaiian species, but it differs strikingly from them all in the large number of primary tubercles within the fasciole, particularly in the posterior interambulacrum; the anterior interambulacra each have 25 to 35 tubercles, the lateral have 28 to 32, and the posterior has 25 to 30. The primary spines are 20 to 45 mm. long and almost perfectly smooth, though many show a few scattered, minute teeth and in some cases these are sufficiently numerous to form imperfect whorls. The test and primaries of the largest specimen are pale fawn-color with the numerous small spines lighter, almost silvery-white, but a specimen 80 mm. long is distinctly reddish, almost dull rose-red on some parts of the test.

Station 5082. Off Omai Saki Light, Japan, 662 fathoms.

" 5083. Off Omai Saki Light, Japan, 624 fathoms.

Four specimens.

Lovenia gregalis Alcock.

Lovenia gregalis Alcock, 1893. Journ. Asiat. Soc. Bengal, **62**, p. 175.

The Lovenias in this collection all belong to a single species and are more closely allied to *gregalis* than to any other species, although they do not agree in every detail with Alcock's description.

Station 4906. Southwest of Koshika Islands, Japan, 369–406 fathoms.

" 4912. Southwest of Koshika Islands, Japan, 391 fathoms.

Five specimens.

Pseudolovenia hirsuta A. Ag. and Cl.

Pseudolovenia hirsuta A. Agassiz and Clark, 1907. Bull. M. C. Z., **50**, p. 255.

These specimens cannot be distinguished from those of the same size from Hawaii.

Station 4906. Southwest of Koshika Islands, Japan, 369–406 fathoms.

Two specimens.

Maretia tuberculata A. Ag. and Clark.

This species is not at all like *alta*, *elevata*, or *elliptica*, and although it is very similar to *planulata* in the form of the test and the petals, the latter are narrower and shorter than in that species. The striking character, however, is the presence of few, very large primary tubercles in the anterior and lateral interambulacra, like those of *alta;* there are 1–3 in the anterior and 3–4 in the lateral spaces. The absence of genital pores and the condition of the petals show that the specimen is immature but it is evidently not the young of any known species. The test is 26 mm. long and 22 mm. wide, and the general color is very light purplish-gray.

Station 4875. Eastern channel, Korea Strait, 59 fathoms.

One specimen.

Echinocardium australe Gray.

Echinocardium australe Gray, 1851. Ann. Mag. Nat. Hist., (2) **7**, p. 131.

The only specimen is immature, 14 mm. long, and almost pure white.

Station 4962. Between Kobe and Yokohama, Japan, 36 fathoms.

One specimen.

Echinocardium dubium A. Ag. and Clark.

The occurrence in the northwestern Pacific of an Echinocardium allied to *flavescens* and *pennatifidum* is interesting. This species is certainly very closely allied to these north Atlantic forms, the only differences worthy of note being in the form and position of the anal system and subanal fasciole. The posterior end of the test does not overhang the anal system at all, but the latter is flush with the test; its vertical diameter is noticeably longer than the transverse. The subanal fasciole is nearly circular and not at all pyriform. The color is pale brown with the numerous small spines almost white, when dry. The largest specimen is 31 mm. long.

Station 4965. Between Kobe and Yokohama, Japan, 191 fathoms.
" 5047. Between Hakodate and Yokohama, Japan, 107 fathoms.
" 5055. Suruga Gulf, Japan, 124 fathoms.

Three specimens.

BRISSINA Gray.

Hemiaster gibbosus A. Ag.

Hemiaster gibbosus A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 210.

The large series collected range in size from 10 to 34 mm. long diameter, and many of them seem to be almost spherical.

Station 4913. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4967. Between Kobe and Yokohama, Japan, 244–253 fathoms.
" 4968. Between Kobe and Yokohama, Japan, 253 fathoms.
" 4970. Between Kobe and Yokohama, Japan, 500–649 fathoms.
" 4971. Between Kobe and Yokohama, Japan, 649 fathoms.
" 4973. Between Kobe and Yokohama, Japan, 600 fathoms.
" 4977. Between Kobe and Yokohama, Japan, 544 fathoms.
" 5053. Suruga Gulf, Japan, 503 fathoms.
" 5054. Suruga Gulf, Japan, 282 fathoms.
" 5056. Suruga Gulf, Japan, 258 fathoms.
" 5083. Off Omai Saki Light, 624 fathoms.
" 5086. Sagami Bay, Hondo, Japan, 292 fathoms.
" 5087. Sagami Bay, Hondo, Japan, 614 fathoms.
" 5088. Sagami Bay, Hondo, Japan, 369–405 fathoms.
" 5093. Off Gulf of Tokyo, Japan, 302 fathoms.

Fifty-five specimens.

Hemiaster globulus A. Ag. and Clark.

The largest Hemiaster collected differs so much from the large specimens of *gibbosus* that we consider it an undescribed species. The test is nearly globular, measuring 36 mm. in length, 35 mm. in width and 33 mm. in height. The posterior end is vertically truncate, while the plastron forms a broad rounded keel. The most striking character, however, is the narrowness of the petals and the length of the posterior pair. In *gibbosus*, the posterior petals are about three-fifths of the length of the lateral ones, while their width is about three-fourths of their own length. In *globulus*, the posterior petals are seven-tenths of the length of the lateral ones, and their width is less than half their own length. In all the specimens of the large series of *gibbosus* no connecting links between the two forms were found. The test is more thickly covered with tubercles and small spines in *globulus* than in *gibbosus*, but the color is not essentially different.

Station 4832. Between Nanao and Tsuruga, Hondo, Japan, 76–79 fathoms.

One specimen.

Brissopsis luzonica A. Ag.

Kleinia luzonica Gray, 1851. Ann. Mag. Nat. Hist., (2) **1**, p. 133.
Brissopsis luzonica A. Agassiz, 1872. Rev. Ech., Pt. 1, p. 95.

There are only a few specimens of this species but they are mostly well preserved.

Station 4911. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4968. Between Kobe and Yokohama, Japan, 253 fathoms.
" 5055. Suruga Gulf, Japan, 124 fathoms.
" 5083. Off Omai Saki Light, Japan, 624 fathoms.
" 5091. Off Gulf of Tokyo, Japan, 197 fathoms.
" 5092. Off Gulf of Tokyo, Japan, 70 fathoms.
Eleven specimens.

Brissopsis Oldhami Alcock.

Brissopsis Oldhami Alcock, 1893. Jour. Asiat. Soc., Bengal, **62**, p. 6 (174).

A large series of this species was taken.

Station 4906. Southwest of Koshika Islands, Japan, 369–406 fathoms.
" 4907. Southwest of Koshika Islands, Japan, 406 fathoms.
" 4911. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4912. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4913. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4915. Southwest of Koshika Islands, Japan, 427 fathoms.
" 4956. Between Kagoshima and Kobe, Japan, 720 fathoms.
" 4957. Between Kagoshima and Kobe, Japan, 437 fathoms.
" 4966. Between Kobe and Yokohama, Japan, 244–290 fathoms.
" 4970. Between Kobe and Yokohama, Japan, 500–649 fathoms.
" 4980. Between Kobe and Yokohama, Japan, 507 fathoms.
" 5053. Suruga Gulf, Japan, 503 fathoms.
" 5054. Suruga Gulf, Japan, 282 fathoms.
" 5082. Off Omai Saki Light, Japan, 662 fathoms.
" 5087. Sagami Bay, Hondo, Japan, 614 fathoms.
" 5088. Sagami Bay, Hondo, Japan, 369–405 fathoms.
Seventy-three specimens.

Aërope fulva A. Ag.

Aërope fulva A. Agassiz, 1898. Bull. M. C. Z., **32**, p. 81.

We refer the fragments of an Aërope, of a bright yellow-brown color, to this Panamic species.

Station 4766. Between Atka Island and Bowers Bank, Bering Sea, 1766 fathoms.

Two specimens (anterior fragments only).

Aceste purpurea A. Ag. and Cl.

Aceste purpurea A. Agassiz and Clark, 1907. Bull. M. C. Z., **50**, p. 259.

The specimens of Aceste collected belong to this Hawaiian species.

Station 4911. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4913. Southwest of Koshika Islands, Japan, 391 fathoms.
Three specimens.

Schizaster japonicus A. Ag.

Schizaster japonicus, A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 212.

There is an excellent series of this species, ranging from 15 to 60 mm. in length.
Station 4939. Kagoshima Gulf, Japan, 85 fathoms.
" 4940. Kagoshima Gulf, Japan, 115 fathoms.
" 4942. Kagoshima Gulf, Japan, 118 fathoms.
" 4943. Kagoshima Gulf, Japan, 119 fathoms.
" 4945. Kagoshima Gulf, Japan, 70 fathoms.
" 4961. Between Kobe and Yokohama, Japan, 33 fathoms.
" 4962. Between Kobe and Yokohama, Japan, 36 fathoms.
" 4964. Between Kobe and Yokohama, Japan, 37 fathoms.
Thirty-one specimens.

Schizaster ventricosus Gray.

Schizaster ventricosus Gray, 1851. Ann. Mag. Nat. Hist., (2) **7**, p. 133.

A remarkably interesting series of this species was taken, ranging from 9 to 74 mm. in length. There is the greatest diversity, shown in the relative length of the anterior and posterior petals and in the angle made by the latter with the longitudinal axis of the body. While it is possible to divide the specimens into three groups, ((1) with short, widely diverging, posterior petals, (2) with long, straight, little diverging, posterior petals, and (3) with very long petals, the posterior pair straight and moderately diverging) it is impossible to draw hard and fast lines between such groups, and although the typical examples of each group are obviously different from each other, it seems best to regard them all as *ventricosus*.
Station 4748. Off Bushy Point, near Yes Bay, Alaska, 185–300 fathoms.
" 4768. Bowers Bank, Bering Sea, 764 fathoms.
" 4775. Bowers Bank, Bering Sea, 584 fathoms.
" 4832. Between Nanao and Tsuruga, Hondo, Japan, 76–79 fathoms.
" 4842. Off Dogo Island, Sea of Japan, 82 fathoms.
" 4968. Between Kobe and Yokohama, Japan, 253 fathoms.
" 4993. Between Otaru, Japan and Korsakov, Saghalin Island, 142 fathoms.
" 5015. Off east coast, southern end of Saghalin Island, 510 fathoms.
" 5029. 48° 22′ 30″ N. × 145° 43′ 30″ W., 440 fathoms.
" 5032. Yezo Strait, Japan, 300–533 fathoms.
" 5033. Yezo Strait, Japan, 533 fathoms.
" 5036. Off south coast of Hokkaido, Japan, 464 fathoms.
" 5037. Off south coast of Hokkaido, Japan, 175–349 fathoms.
" 5039. Off south coast of Hokkaido, Japan, 269–326 fathoms.
" 5040. Off south coast of Hokkaido, Japan, 140–269 fathoms.
" 5045. Off south coast of Hokkaido, Japan, 359 fathoms.
" 5046. Between Hakodate and Yokohama, Japan, 82 fathoms.
" 5047. Between Hakodate and Yokohama, Japan, 107 fathoms.

Station 5049. Between Hakodate and Yokohama, Japan, 182 fathoms.
" 5051. Between Hakodate and Yokohama, Japan, 399 fathoms.
" 5053. Suruga Gulf, Japan, 503 fathoms.
" 5054. Suruga Gulf, Japan, 282 fathoms.
" 5055. Suruga Gulf, Japan, 124 fathoms.
" 5056. Suruga Gulf, Japan, 258 fathoms.
" 5059. Suruga Gulf, Japan, 197–297 fathoms.
" 5067. Suruga Gulf, Japan, 293 fathoms.
" 5072. Suruga Gulf, Japan, 148–284 fathoms.
" 5087. Sagami Bay, Hondo, Japan, 614 fathoms.
" 5088. Sagami Bay, Hondo, Japan, 369–405 fathoms.
" 5091. Off Gulf of Tokyo, Japan, 197 fathoms.
" 5092. Off Gulf of Tokyo, Japan, 70 fathoms.
" 5093. Off Gulf of Tokyo, Japan, 302 fathoms.

Two hundred and seventy-five specimens.

Periaster rotundus A. Ag. and Clark.

This species is extraordinarily like *limicola* from the Gulf of Mexico, as it has two genital pores and the general shape of the test is of that species. The posterior petals are shorter in *rotundus* (just one-half the lateral ones, instead of nearly two-thirds as in *limicola*) and have fewer pairs of pores relatively (less than 65 per cent of the number in the lateral petals instead of over 75 per cent as in *limicola*). The mouth is nearer the centre of the actinal surface in *rotundus* (two-fifths of the long axis from the anterior end, instead of one-third as in *limicola*). The test is 37 mm. long, 35 mm. wide, and 31 mm. high. The color of the test is pale brown, and the numerous spines are silvery-white (dry).

Station 4946. Between Kagoshima and Kobe, Japan, 39 fathoms.

One specimen.

Periaster fragilis A. Ag. and Clark.

The specimen upon which this species is based is obviously immature, and has no genital openings. At first sight it might be mistaken for a young Schizaster; but comparison with specimens of *S. japonicus* and *S. ventricosus* of the same size and smaller shows at once that such is not the case. In young Schizasters the area occupied by the petals and peripetalous fasciole covers most of the abactinal surface, the abactinal system is far back of the center, and the anterior ambulacral furrow is already deep. None of these characters are found in the specimen under discussion. That it is not the young of the preceding species is shown by the extraordinary shortness of the posterior petals, the narrower, flatter test, and the character of the actinostome. The test is 16 mm. long, 14 mm. wide, and 10 mm. high. The lateral petals are 5.3 mm. long and have 18 pairs of pores,

while the posterior petals are 2 mm. long and have only 7 pairs of pores. The labial plate is short and in contact with only one ambulacral plate on each side, and the actinostomal membrane carries only very small plates, while in *rotundus* the labial plate is long and in broad contact with two ambulacral plates on each side, and the actinostome is covered by four large and six or seven smaller plates. We are forced, therefore, to regard this specimen as a young example of an undescribed species. The test and spines are nearly white, while the peripetalous fasciole is purple.

Station 4913. Southwest of Koshika Islands, Japan, 391 fathoms.

One specimen.

Bulletin of the Museum of Comparative Zoölogy

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REPORTS ON THE SCIENTIFIC RESULTS OF THE EXPEDITION TO THE EASTERN TROPICAL PACIFIC, IN CHARGE OF ALEXANDER AGASSIZ, BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," FROM OCTOBER, 1904, TO MARCH, 1905, LIEUT. COMMANDER L. M. GARRETT, U. S. N., COMMANDING.

XI.

DIE XENOPHYOPHOREN.

VON FRANZ EILHARD SCHULZE.

WITH ONE PLATE.

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No. 6. — *Reports on the Scientific Results of the Expedition to the Eastern Tropical Pacific, in charge of* ALEXANDER AGASSIZ, *by the U. S. Fish Commission Steamer "Albatross," from October, 1904, to March, 1905,* LIEUTENANT COMMANDER L. M. GARRETT, *U. S. N., Commanding.*

XI.

Die Xenophyophoren. Von FRANZ EILHARD SCHULZE.[1]

IM Jahre 1892 hat Goës im Bulletin of the Museum of Comparative Zoölogy at Harvard College, Vol. XXIII, Nr. 5, III, p. 195–198 unter der Bezeichnung *Neusina agassizi* einen seiner Ansicht nach neuen Organismus als "a peculiar type of arenaceous Foraminifer from the American tropical Pacific" nach mehreren Exemplaren beschrieben, welche von Alexander Agassiz im Jahre 1890 bei einer seiner Albatross-Expeditionen in der Nähe der Galapagos-Inseln an folgenden drei Stationen erbeutet waren:

Nummer der Albatross-Station.	Position.		Tiefe in Meter.
	Breite.	Länge.	
	° ′	° ′	
3399	1 7 N.	81 4 W.	3097
3414	10 14 N.	96 28 W.	3972
3415	14 46 N.	98 40 W.	3415

Die gewissen Algen, z. B. *Padina pavonia*, äusserlich sehr ähnlichen, blattförmigen Körper von Kinderhand-Grösse und 0,5–2 mm. Dicke zeigen nach Goës "a triangular, fan-like or reniform figure, with more or less strongly arcuate edge. . . . Sometimes the shape is that of a biauriculated leaf, produced much more in breadth than in height. The edge is often undulated in broad folds, and sometimes new individuals sprout

[1] This paper has also been published in the Sitzungsberichte der Gesellschaft naturforschender Freunde, Berlin, 1906, p. 205–229, 1 Taf.

from the broad side, forming irregularly shaped clusters of two or three individuals. The chambers constitute arcuated, concentric, more or less complete bands, increasing in length with age, forming a fan-like growth, commencing with a pointed triangular juvenile stage. . . . The chamber wall is thin, often wrinkled, and here and there pierced by irregularly formed pores of different size. In some places a faint striation running perpendicular to the chamber sutures across the chamber wall can be discovered, probably indicating the divisions into chamberlets. The interstice between the two side walls is crossed by numberless irregular partitions, forming masses of small chambers of different size and form, giving to the structure a sponge-like texture. The color is commonly sooty, with shades in dark olive; when dried, it becomes grayish clay-colored."

Als auffälligsten Charakter bezeichnet aber Goës mit Recht das reichliche Vorkommen netzartig verbundener Bündel von feinen, gelblichen, aus einer chitinartigen Substanz bestehenden, 3–6 μ dicken Fäden, welche ein den ganzen Körper durchsetzendes, feine Sandteilchen und Schalenreste umschliessendes Stroma bilden.

Am Schlusse seines Aufsatzes macht Goës darauf aufmerksam, dass eine von Jullien vor der Küste von Liberia in 4 bis 5 Meter Tiefe gedredgter und von Schlumberger im Jahre 1890 in den Mém. Soc. Zool. de France, Tom. III, p. 211 als *Jullienella foetida* Schlbgr. beschriebener Organismus wahrscheinlich mit seiner *Neusina* nahe verwandt sei, obwohl bei ihm kein aus dünnen Chitinfäden bestehendes Stroma, wohl aber eine mehr einfache und regelmässige Kammerbildung, sowie eigentümliche röhrenförmige Randausläufer vorkommen.

Goës ist geneigt, seine neue Gattung *Neusina* nebst Schlumbergers *Jullienella* als Repräsentanten einer besonderen neuen Foraminiferenfamilie hinzustellen.

Bald nachdem die Arbeit von Goës erschienen war, wies R. Hanitsch in der englischen Zeitschrift "Nature" 1893, Vol. XLVII, p. 365 und 439 darauf hin, dass die von Goës beschriebenen und als Sandforaminiferen gedeuteten (*Neusina agassizi* genannten) Tiefseegebilde schon im Jahre 1889 von Haeckel in seinem Report on the deep sea Keratosa (The Voyage of H. M. S. Challenger, Zoology, Vol. XXXII, p. 62 und 63) unter der Bezeichnung *Stannophyllum zonarium* Hkl. als Tiefsee-Hornspongien ausführlich beschrieben und abgebildet seien.

In gleichem Sinne äusserte sich in demselben Bande Vol. XLVII, p. 390 der "Nature" 1893 F. G. Pearcey, welcher zwar auch von der

völligen Übereinstimmung der *Neusina agassizi* Goës mit Haeckels *Stannophyllum zonarium* überzeugt ist, aber auf Grund einer Prüfung des betreffenden von Haeckel benutzten Challenger-Materiales die Auffassung Haeckels von der Zugehörigkeit des *Stannophyllum* und verwandter Formen (meiner Xenophyophoren) zu den Spongien bestreitet und sie (wie Goës seine *Neusina*) zu den *Sandforaminiferen* stellt.

"In not one species," so sagte er l. c. pag. 390, "could I find the slightest trace of any of the flagellated chambers characteristic of sponges."

Diese Mitteilung von F. G. Pearcey hat dann R. Hanitsch veranlasst, bald darauf in demselben Bande der "Nature" 1893 noch einmal in dieser Sache das Wort zu ergreifen und l. c. pag. 439 darauf hinzuweisen, dass zwar die konzentrischen Linien an den flachen Seiten des blattförmigen *Stannophyllum* mehr dem Wachstumstypus der Foraminiferen als der Spongien entsprächen, dass aber "the chitinous lining in the tube-like body of some Foraminifera certainly bears not the slightest resemblance to the distinct fibrous stroma of *Stannophyllum*, which reminds me much more of the filaments of the true horny sponge *Hircinia*." Auch meinte Hanitsch, dass "the presence of oscula, pores, subdermal cavities, horny skeleton, etc." (auch ohne Nachweis von Geisselkammern) "are sufficient to characterise the form as a sponge," und kam inbezug auf die systematische Stellung der mit *Stannophyllum zonarium* Haeckel identischen *Neusina agassizi* Goës zu folgendem Schluss: "I do not as yet see sufficient reason to differ from Haeckel in regarding it as a sponge, although I have never observed flagellated chambers and cells any more than he."

Ich selbst habe dann im Jahre 1905 in den "Wissensch. Ergebnissen der deutschen Tiefsee- (Valdivia) Expedition, Bd. XI," die Resultate von Untersuchungen mitgeteilt, welche an dem mir damals zugänglichen Materiale der von Haeckel als *Tiefsee-Hornspongien*, von mir aber als eine besondere *Rhizopoden*-Gruppe, "*Xenophyophora*," aufgefassten Organismen angestellt waren.

Das Material zu diesen Studien setzte sich zusammen

1. aus den reichen Schätzen der Challenger-Expedition, welche schon im Jahre 1889 mit Beigabe zahlreicher vortrefflicher Abbildungen von Haeckel im Challenger Report, Zoology, Vol. XXXII, beschrieben, mir jedoch durch das besonders dankenswerte freundliche Entgegenkommen des Direktors des British Museum of nat. hist. grösstenteils zur nochmaligen Untersuchung anvertraut waren;

2. aus den zwar nicht zahlreichen, aber recht gut konservierten Objekten, welche von der ersten deutschen Tiefsee- (Valdivia) Expedition heimgebracht und mir von deren Leiter, Herrn Prof. C. Chun, zur Bearbeitung überlassen waren; sowie

3. aus jenen Xenophyophoren, welche von der Albatross-Expedition der Jahre 1889–90 erbeutet und mir grösstenteils (d. h. mit Ausnahme der von A. Goës studierten Exemplare) von Herrn Prof. Al. Agassiz zur wissenschaftlichen Verwertung geliehen waren.

Als einige für die Auffassung der ganzen Organismengruppe besonders wichtige allgemeine Ergebnisse meiner Untersuchungen führe ich hier folgende auf.

In einem aus Fremdkörpern (Xenophya) *zusammengesetzten lockeren Stützgerüst von verschiedener (aber für die einzelnen Gattungen und Arten meist sehr charakteristischer) Form findet sich ein System von entweder baumartig verzweigten oder netzförmig verbundenen, hier und da mit Endöffnungen versehenen, dünnwandigen Röhren, welche entweder ein* KERNREICHES PLASMODIUM *oder zahlreiche rundliche Kotballen* (STERKOME) *umschliessen. Während das Plasmodium gewöhnlich viele kleine, glatte, stark lichtbrechende, farblose Körnchen von Baryumsulfat (Granellen) enthält und nur gelegentlich (nach Ausstossen dieser letzteren) in einzelne rundliche Zellen (Gameten?) zerfällt, finden sich zwischen den Sterkomen fast immer gelbliche oder rötliche Konkremente von Eisenoxydhydrat (Xanthosome).*

Nach dem vorwiegenden Besitze der GRANELLEN *habe ich die das Plasmodium enthaltenden, meist mehr oder weniger isolierten Röhren als* GRANELLARE, *die mit Sterkomen gefüllten Röhren dagegen als* STERKOMARE *bezeichnet.*

Aus den Endöffnungen der Granellare ragt zuweilen ein hyaliner oder mit Granellen durchsetzter Plasmaklumpen frei hervor.

Bei einer (systematisch jedenfalls zu sondernden) Hauptabteilung der Xenophyophoren, welche ich mit Haeckel nach einer Gattung Stannoma *Hkl. als eine besondere Familie* Stannomidae, STANNOMIDEN, *bezeichne, tritt zu den Fremdkörpern als ein eigenartiger, vom Organismus selbst produzierter Bestandteil des Stützgerüstes noch ein System zarter, einfacher oder verästelter Fäden, der* LINELLEN, *hinzu, welche sich in Menge zwischen den übrigen Festteilen ausspannen und dem Körper eine mehr filzartige, biegsame Konsistenz verleihen.*

Die andere, dieser Linellen entbehrende Hauptgruppe der Xenophyophoren wird nach der Gattung Psammina *als* Psamminidae, PSAMMINIDEN, *bezeichnet und zeigt wegen der direkten festen Verlötung*

der Xenophya *einen mehr starren und brüchigen Charakter des ganzen Körpers.*

Zur Familie der *Psamminidae* rechnete ich ausser den schon von Haeckel charakterisierten Gattungen *Psammina* Hkl., *Cerelasma* Hkl., *Holopsamma* Carter und *Psammopemma* Marshall noch eine neue Gattung *Psammetta* F. E. Sch., deren damals zunächst einzige Species in der Gestalt so sehr einem menschlichen Blutkörperchen gleicht, dass ich sie *erythrocytomorpha* F. E. Sch. genannt habe. Indem ich beim Studium der feineren Struktur- und Bauverhältnisse der Xenophyophoren von den verhältnismässig gut konservierten Stücken dieser letzteren Spezies, welche die deutsche Tiefsee- (Valdivia) Expedition erbeutet hatte, ausging, gelang es mir, eine befriedigende Einsicht in die Organisationsverhältnisse der ganzen Gruppe zu gewinnen.

Von den *Stannomidae* standen mir Vertreter der drei Gattungen *Stannoma* Hkl., *Stannophyllum* Hkl. und *Stannarium* Hkl. zu Gebote.

Mit diesem, im ganzen aus 2 Familien, 8 Gattungen und 22 Arten bestehenden Materiale konnte ich in den " Wissensch. Ergebn. der ersten deutschen Tiefsee-Expedition" Bd. XI, im Jahre 1905 eine Charakteristik, systematische Übersicht und Bestimmungstabelle aller damals bekannten Xenophyophoren, sowie auch eine tabellarische und kartographische Darstellung ihrer geographischen Verbreitung, also eine Monographie der Xenophyophoren geben.

Seitdem ist mir durch das Entgegenkommen des Leiters der holländischen Siboga-Expedition, des Herrn Prof. Max Weber, noch ein weiteres, aus dem Gebiete des Malayischen Archipels stammendes Xenophyophoren-Material zugegangen, über welches ich vor kurzem in einer eigenen Abhandlung: Die Xenophyophoren der Siboga-Expedition in dem Werke: " Siboga-Expeditie," Vol. IV, bis 1906 ausführlich berichtet habe. Von besonderem Interesse erwies sich dabei eine südlich von Celebes, dicht vor der Mündung der Boni-Bai auf Schlammboden in Menge gefundene, der *Psammetta erythrocytomorpha* F. E. Sch. in Bau und Struktur sehr nahestehende, aber durch ihre rein kugelige Gestalt ausgezeichnete neue Form, welche ich näher untersucht und l. c. als *Psammeta globosa* F. E. Sch. beschrieben habe.

Jetzt ist mir durch die Güte des Herrn Prof. Al. Agassiz noch das Xenophyophoren-Material zur Untersuchung und Beschreibung anvertraut, welches er bei seiner in den Jahren 1904/5 ausgeführten Albatross-Expedition erbeutet hat.

Obwohl diese Kollektion nur schon bekannte Arten enthält, und eine eingehende mikroskopische Untersuchung auch hinsichtlich des feineren Baues dieser merkwürdigen Organismen keine wesentlich neuen Tatsachen ergeben hat, ist sie mir doch wertvoll geworden durch die Gelegenheit zur Prüfung des früher Ermittelten an zahlreichen weiteren Objekten anderer Provenienz und besonders durch die nicht unerhebliche Erweiterung unserer Kenntnis von der geographischen Verbreitung einiger Formen.

Im Ganzen setzt sich dies an Individuen ziemlich reiche Material zusammen aus 5 Arten, welche sämtlich zu den *Stannomiden* gehören, nämlich

Stannoma dendroides Hkl.,
Stannoma coralloides Hkl.,
Stannophyllum zonarium Hkl.,
Stannophyllum globigerinum Hkl., und
Stannophyllum alatum (Hkl.) = (*Stannarium alatum* Hkl.).

Ich bespreche jede einzelne Form für sich und beginne mit

Stannoma dendroides Hkl.

Die Charakteristik, welche Haeckel bei der Aufstellung des Speziesbegriffes *Stannoma dendroides* Hkl. im Jahre 1889 im Challenger Report l. c. p. 72 gegeben hat, bezieht sich vorwiegend auf die äussere Körperform. Sie lautet: "arborescent, irregularly branched (partly dichotomous, partly polychotomous), with slender cylindrical branches tapering towards the conical distal end. Branches free, without anastomoses. The body of the tree-like sponge is 30 to 50 mm. high, 20 to 30 mm. broad, very soft and flexible, in the dry state friable. The short stem, 10 to 20 mm. in height, 3 to 5 mm. in thickness, is either cylindrical or inversely conical, tapering towards the small base, and divided into three to six stout main branches, 3 to 4 mm. in diameter. These divide again into secondary and tertiary branches of varying lengths, between 5 and 20 mm. The branches are slightly curved, and gradually taper from 3 or 2 mm. to 0.5 mm. or less in thickness; the conical end also tapers gradually."

An den feinen, nur 1–3 μ dicken Linellen, welche nicht zu Bündeln vereinigt, sondern mehr isoliert in verschiedener Richtung verlaufen, beobachtete Haeckel keine Verzweigungen. Als Xenophyen fand er vorwiegend Radiolarien-Skelette und Hexactinelliden-Nadeln.

Indem ich in meiner Monographie im Jahre 1905 dieser Schilderung noch einige Züge hinzufügte, hob ich hervor, dass die Verzweigung der

baumartig verästelten Stöckchen, wenn auch nicht ausschliesslich, so doch vorwiegend in ein und derselben Ebene erfolgt, und dass das untere verschmälerte Stielende nicht selten in eine lockere, ganz aus Linellen bestehende Faser-Masse ausläuft.

Obwohl nun das mir jetzt zur Disposition gestellte, grade an *Stannoma dendroides* Hkl. ziemlich reiche Material der Albatross-Expedition 1904/5 zunächst zu einer wesentlichen Abänderung dieser Charakteristik keine Veranlassung bietet, habe ich es doch benutzt, um über einzelne Fragen Aufklärung zu gewinnen, die bisher noch keine befriedigende Lösung erfahren hatten. Dahin gehört z. B. die Vorstellung, welche wir uns von der Art der Befestigung der ganzen Gebilde am Boden zu machen haben. Nach Haeckels oben wörtlich wiedergegebenen Darstellung ist das untere Stielende von *Stannoma dendroides* "either cylindrical or inversely conical tapering towards the small base." Trotzdem zeigt die auf Taf. III in Fig. 1 seiner Abhandlung gegebene Abbildung eines ganzen Stöckchens von *Stannoma dendroides* eine flache basale *Ausbreitung* des unteren Stielendes, welche auf einer annähernd platten festen Unterlage aufsitzt.

Ich selbst hatte früher an den zahlreichen (weit über hundert) Exemplaren von *Stannoma dendroides* Hkl., welche ich in dem Xenophyophoren-Material der Albatross-Expedition von 1899–1900 vorfand, zwar die meisten mit einem einfach konisch-verschmälerten glatten unteren Ende aufhören sehen, jedoch bei manchen Stücken am Stielende die schon mehrfach erwähnte und in meiner Xenophyophoren-Monographie Taf. IV, Fig. 1–3 abgebildete lockere büschelförmige Fasermasse der Linellen gefunden.

Ich nahm damals an, dass alle Stöckchen mit einem solchen Faserschopfe regelmässig an irgend welchen Festkörpern des Bodens angeheftet gewesen seien, und dass, wo ein solcher Schopf fehlt, er nur beim Fange abgerissen wäre.

Als ich jetzt aber die zahlreichen Exemplare der Albatross-Expedition vom Jahre 1904/05 auf die Beschaffenheit ihres unteren Stammendes näher prüfte und dabei auch die mir noch zugängigen Stücke früherer Expeditionen zum Vergleich heranzog, fiel es mir auf, dass in dieser Hinsicht sehr auffällige Unterschiede bestehen. Es zeigte sich nämlich, dass von den über 50 Stücken, welche von der Albatross-Station 4742 — 0° 34′ N.; 117° 15,8′ W. stammen, nur wenige einen basalen Faserschopf besitzen, die meisten vielmehr mit einem *einfachen* glatten konischen oder abgerundeten Stielende aufhören.

Ebenso ist es bei der Mehrzahl aller von der Albatross-Expedition 1899/1900 herrührenden Stücke.

Ein wesentlich anderes Verhalten zeigen dagegen einige Stöckchen der Albatross-Expedition 1904/05, da sie unten nicht mit einer Verschmälerung, sondern im Gegenteil mit einer quer abgestutzten Verbreiterung enden. Diese letztere ist bei zwei Stücken kolbig verdickt, bei einem aber trompetenförmig verbreitert. Die annähernd plane Endfläche weist bei allen dreien kleine Rauhigkeiten auf, als ob sie von einer rauhen Unterlage abgerissen wäre, und ist bei einem Stück noch mit zahlreichen grösseren Foraminiferenschalen besetzt.

Mit einer ähnlichen terminalen Stielverbreiterung muss auch jenes *Stannoma dendroides*-Stöckchen einer festen Unterlage aufgesessen haben, welches Haeckel in seinem Werke: Deep sea Keratosa der Challenger-Expedition l. c. Plate III, Fig. 1 abgebildet hat.

Es hat sich herausgestellt, dass bei der grössten Zahl aller untersuchten Stücke das untere Stielende sich konisch verjüngt und eine glatte oder leicht höckerige Oberfläche hat, während es bei einzelnen Stöckchen in ein lockeres Linellenbüschel ausläuft, bei einigen anderen Exemplaren dagegen sich terminal verdickt und mit einer verbreiterten quer abgestutzten Basalfläche endet.

Dementsprechend wird man wohl annehmen müssen, dass die Mehrzahl der *Stannoma dendroides*-Stöckchen mit ihrem Stiele lose im Sand oder Schlamm stecken, wie etwa eine *Pennatula*, dass andere dagegen entweder mit einem basalen Linellenbüschel an Fremdkörpern des Meeresgrundes angeheftet sind oder mit einer verbreiterten Endfläche des Stieles der nahezu ebenen Oberfläche einer derben (Foraminiferen-) Sandmasse, vielleicht auch einer kompakten festen Unterlage aufsitzen.

Noch ein anderer Umstand ist mir bei einer vergleichenden Durchsicht aller mir jetzt vorliegenden zahlreichen Exemplare von *Stannoma dendroides* Hkl. aufgefallen, dass nämlich die Hauptäste, welche zunächst aus dem einfachen basalen Stiel durch mehr oder minder weitgehende Verzweigung entstehen, keineswegs immer einen kreisrunden Querschnitt zeigen, sondern oft stark *abgeplattet* sind. Diese Abplattung ist dann stets in gleicher Richtung erfolgt, so dass hand- oder fächerförmige Gebilde entstanden sind, deren untere platte Hauptäste sich in ein und derselben Ebene ausbreiten. Nur die letzten Endäste sind drehrund und zwar meist einfach fingerförmig mit geringer Verschmälerung an dem abgerundeten freien Distalende.

Stannoma dendroides Hkl. ist bei der unter Alexander Agassiz in den Jahren 1904/5 ausgeführten Albatross-Expedition an folgenden 4 Stationen erbeutet.

Nummer der Station.	Position.		Tiefe in Meter.	Stückzahl.
	Breite.	Länge.		
	° ′	° ′		
4649	5 17 S.	85 19 5 W.	4090	1
4717	5 10 S.	98 56 W.	3937	1
4721	8 7.5 S.	104 10.5 W.	3814	3
4742	0 3.4 N.	117 15.8 W.	4243	circa 50

Stannoma coralloides Hkl.

In der Gattung *Stannoma* kennen wir neben *St. dendroides* Hkl. noch eine durch die reichlichen Anastomosen ihrer 4–8 mm. langen und nur 2–3 mm. dicken, drehrunden und überall gleich starken Gerüstbalkenstücke ausgezeichnete Spezies von 20–40 mm. Gesamtdurchmesser. Die meist dichotomische Verästelung des Balkensystems erfolgt nicht in ein und derselben Ebene, sondern in verschiedenen Richtungen.

Bei dieser als *Stannoma coralloides* Hkl. bezeichneten, der vorigen im feineren Bau sehr ähnlichen Form fand Haeckel "the fine spongin-fibres much more numerous, larger and more richly developed," und als *Xenophya* fast ausschliesslich Radiolarien.

In den wenigen aus oberen abgerissenen Körperpartien bestehenden Exemplaren, welche mir früher bei Abfassung meiner Monographie allein zu Gebote standen, konnte ich nur sehr zarte Linellen von höchstens 2 μ Durchmesser sehen, während Haeckel bei *St. coralloides* grade die Stärke der Linellen hervorhebt, welche er meistens bis 4 μ, ja sogar gelegentlich 5 bis 10 μ dick fand. Bei den mir jetzt von der Albatross-Expedition 1904/05 vorliegenden Stücken, welche in den unteren Körperregionen etwas besser erhalten sind, finde ich nun zwar (in den untersten Partien) zwischen zahllosen feinen Linellen von 1–2 μ Dicke auch einige dickere (bis zu 4 μ), aber die grosse Mehrzahl ist doch bedeutend dünner als bei *Stannoma dendroides*, wo sie ja durchschnittlich 3–4 μ stark gefunden werden. Ich muss also dabei bleiben, dass für *Stannoma coralloides* die erheblich dünneren Linellen (*St. dendroides* gegenüber) charakteristisch sind.

Von Interesse erscheint mir ferner der Umstand, dass bei einem der neuen Albatross-Exemplare einzelne der untersten, abwärts gerichteten Balken in je ein lockeres Linellenbüschel auslaufen. Auch hier dürfte es sich, ebenso wie bei dem oben erwähnten basalen Linellenschöpfen des Stieles von *Stannoma dendroides*-Bäumchen um eine Einrichtung

zur Befestigung des ganzen Stockes an kleinen festen Körpern des Schlammgrundes handeln.

Wie bei den früher bekannt gewordenen Exemplaren bestehen die *Xenophya* fast ausschliesslich aus Radiolarien.

Die fünf etwa kirschgrossen Exemplare von *Stannoma coralloides*, welche die Albatross-Expedition 1904/05 mitgebracht hat, stammen sämtlich von der Station 4742 — 0° 3.4′ N.; 117° 15.8′ W. — welche in 4243 Meter Bodentiefe einen feinen, von Foraminiferen und Radiolarien durchsetzten Schlick ziegte.

Stannophyllum zonarium Hkl.

Obwohl mir von jenen Gebilden, welche Goës unter der Bezeichnung *Neusina Agassizi* Goës als Foraminiferen beschrieben hat, keine Originalstücke zur Untersuchung zugängig gewesen sind, muss ich sie doch auf Grund seiner eigenen (zu Anfang dieser Abhandlung pag. 206 ausführlich mitgeteilten) Darstellung und den beigegebenen Abbildungen für *Xenophyophoren* halten und wie Hanitsch und Pearcy dem Formenkreis von *Stannophyllum zonarium* Hkl. zurechnen. Gerechtfertigt erscheint dies ausser durch die weitgehende Übereinstimmung der Körperform und des Baues besonders durch das von Goës selbst hervorgehobene reichliche Vorkommen der eigenartigen und für die Xenophyophoren-Familie der *Stannomidae* so überaus charakteristischen Linellen.

Als eine nahe Verwandte der *Neusina* hat Goës ferner (wie schon oben pag. 206 erwähnt wurde) die von Schlumberger zuvor als Foraminifere beschriebene *Jullienella foetida* Schlumberger hingestellt.

Um diesen merkwürdigen Organismus aus eigener Anschauung kennen zu lernen, habe ich mich durch freundliche Vermittelung des Herrn Prof. Raphael Blanchard an den Direktor der geologischen Sammlung der Sorbonne, Herrn Prof. Haug, gewandt, welcher die grosse Güte hatte, mir eines der in seinem Laboratoire in trockenem Zustande aufbewahrten Exemplare von Schlumbergers *Jullienella* nebst einigen Fragmenten zur Untersuchung anzuvertrauen. Ich habe mich davon überzeugt, dass in diesen von Schlumberger vortrefflich beschriebenen und naturgetreu abgebildeten Gebilden *keine* Linellen vorkommen. Auch konnte ich weder in der kompakten harten Schale, noch in den hier und da vorhandenen Inhaltsresten irgend welche Spuren von Sterkomaren oder Granellaren resp. den charakteristischen Granellen auffinden. Dagegen liess sich zwischen den beiden festen Grenzplatten das schon von Schlumberger erkannte System undeutlich geschiedener,

sehr unregelmässiger Hohlräume, wie sie vielen Sandforaminiferen zukommen, leicht nachweisen.

Ich kann daher die *Jullienella* nicht für eine Xenophyophore, sondern muss sie wie der erste Beschreiber für eine *Foraminifere* halten.

Bei der Untersuchung des reichlichen, über 100 Stücke betragenden Materiales von *Stannophyllum zonarium* Hkl. habe ich zunächst die *äussere Gestalt* der bis zu Kinderhand-grossen Exemplare berücksichtigt. Neben der Hauptmasse, welche die schon von Haeckel, Goës und mir früher ausführlich beschriebene und mehrfach abgebildete einfache gestielte Blattform mit einem an beiden Flächen ausgeprägten System konzentrischer, dem freien oberen Konvexrande parallel laufender Furchen zeigt, finden sich zahlreiche Exemplare, welche unter Verlust des Stieles zu einer nieren-, bohnen- oder sichelförmigen Platte geworden sind, wie sie ähnlich von Goës in seiner Fig. 9, von mir in meiner Monographie auf Taf. V, Fig. 2 dargestellt ist. Dabei hängen gewöhnlich von den schmalen Seitenrändern der einzelnen konvexen Bandzonen der Platte ausgefranste Linellenbüschel herab, wie sie auch schon von Goës und mir früher beschrieben und abgebildet sind. Nicht selten erheben sich von der Seitenfläche einer Platte ziemlich rechtwinklig aufsitzende kleine platte Auswüchse von gleicher Beschaffenheit wie die Platte selbst, von mehreren Millimetern Höhe und von sehr verschiedener Gestalt. Einmal sah ich auch an der Seitenfläche eines sonst normalen Exemplares ein anderes gleich grosses und ebenfalls typisches Stück mit einem langen verschmälerten, ziemlich drehrunden und an der Basis etwas verbreiterten Stiele fest aufsitzen.

Dieser letztere Fall scheint mir deshalb wichtig, weil er darauf hindeutet, dass die ganzen Gebilde normaler Weise zunächst wirklich mit der verbreiterten Basis ihres Stieles am Meeresgrunde anderen festen Körpern oder Sandflächen aufsitzen, so wie es Haeckel in seinen Abbildungen dargestellt hat.

Freilich scheint hier grade der Stiel besonders leicht der Degeneration anheimzufallen und zwar zunächst durch Auflockerung und Auffaserung zu einem einfachen Linellenbüschel. Später dürfte er durch Vergrabensein im Sande oder Schlick zur völligen Auflösung und zum Abfallen von dem Körper selbst genötigt werden, ähnlich wie auch die unteren Seitenrandpartien der ganzen Platte. Gut erhaltene Stiele sind bei *Stannophyllum zonarium* nur selten anzutreffen.

Dafür, dass nach dem Zugrundegehen des Stieles der blattförmige Körper gewöhnlich noch mit seinen unteren Seitenrändern im Schlamme steckt, spricht der so häufige Besatz dieser letzteren mit Linellenbüscheln.

Zuweilen aber habe ich auch solche Linellenbüschel aus einer der beiden Seitenflächen der Körperplatte schräge abwärts hervorstehen sehen; was dann darauf hinweisen dürfte, dass hier der ganze Körper mit dieser Seitenfläche auf dem Schlamme oder Sande flach oder schräge aufgelegen hat.

Stannophyllum zonarium Hkl. ist von der Albatross-Expedition 1904/05 an folgenden Stationen erbeutet:

Nummer der Station.	Position.		Tiefe in Meter.	Stückzahl.
	Breite.	Länge.		
	° ′	° ′		
4647	4 33 S.	87 42.5 W.	3667	ca. 40
4649	5 17 S.	85 19.5 W.	4090	ca. 80
4651	5 41 S.	82 59.7 W.	4066	ca. 50
4653	5 47 S.	81 24 W.	980	1
4656	6 54.6 S.	83 34.3 W.	4066	ca. 10
4658	8 29.5 S.	85 35.6 W.	4334	2
4666	11 55 S.	84 20.3 W.	4755	1
4717	5 10 S.	98 56 W.	3937	11
4721	8 7.5 S.	104 10.5 W.	3814	4
4742	0 3.4 N.	117 15 8 W.	4243	ca. 50

Stannophyllum globigerinum Hkl.

Die durch grosse Weichheit und Schlaffheit des ganzen Körpers, sowie durch reichlichen Gehalt an verhältnismässig grossen Foraminiferenschalen ausgezeichnete Spezies *Stannophyllum globigerinum* Hkl. entbehrt des bei *St. zonarium* stark ausgeprägten dichteren Linellenfilzes der beiden planen Grenzflächen.

Während manche Exemplare noch eine Andeutung jener bei *St. zonarium* so deutlich hervortretenden Zonen zeigen, welche durch die dem oberen konvexen Scheibenrande parallel laufenden beiderseitigen Furchen der Scheibe getrennt werden, lässt sich bei anderen davon nichts mehr erkennen. Wo der stets etwas abgeplattete Stiel vorhanden ist, geht er meistens in ein terminales Linellenbüschel aus, seltener endet er quer abgestutzt.

Verwachsungen zweier Stücke, sowie unregelmässig gestaltete leisten- oder plattenförmige Erhebungen auf einer oder beiden Seitenflächen kommen zuweilen vor.

Neben den als *Xenophya* dominierenden Foraminiferen finden sich überall auch zahlreiche Radiolarienskelette, seltener Kieselnadeln oder anderweitige Fremdkörper.

Gefunden ist *Stannophyllum globigerinum* Hkl. an folgenden vier Stationen der Albatross-Expedition 1904/05:

Nummer der Station.	Position.		Tiefe in Meter.	Stückzahl.
	Breite.	Länge.		
	° ′	° ′		
4647	4 33 S.	87 42.5 W.	3667	1
4717	5 10 S.	98 56 W.	3937	1
4721	8 7.5 S.	104 10.5 W.	3814	3
4742	0 3.4 N.	117 15.8 W.	4243	16

Stannophyllum alatum (Hkl.) = Stannarium alatum Hkl.

Als Haeckel die Gattung *Stannarium* für solche Stannomiden aufstellte, deren lamellöser Körper seitliche Flügelplatten aufweist, machte er selbst schon auf die enge Verwandtschaft derselben mit *Stannophyllum* aufmerksam, aus welcher sie seiner Ansicht nach durch seitliches Auswachsen neuer Platten entstanden sein dürfte.

Das mir jetzt vorliegende Material der Albatross-Expedition 1904/05 enthält einige Stücke, welche in der äusseren Gestalt zwar ganz mit Haeckels *Staunarium alatum* übereinstimmen, in den meisten übrigen Charakteren aber so wenig von der einfache Blattform aufweisenden Gattung *Stannophyllum* abweichen, dass ich sie in diese letztere vielgestaltige Gattung stellen muss.

Dies dürfte sich um so mehr rechtfertigen, als ja bei einigen *Stannophyllum*-Arten schon gelegentlich geringe leisten- oder plattenförmige Erhebungen an den Seitenflächen des blattförmigen Körpers gefunden sind.

Ob es sich übrigens empfiehlt, den von Haeckel aufgestellten Speziesbegriff als solchen festzuhalten oder die recht verschiedenartigen Stücke, welche diese merkwürdige Flügelbildung zeigen, an schon bestehende *Stannophyllum*-Arten anzuschliessen resp. zu verteilen, kann zweifelhaft erscheinen. Ich ziehe zunächst das erstere vor und halte einstweilen die Ausbildung der grossen senkrechten einfachen oder gelappten *Flügelplatten*, welche zu 3, 4 oder selbst mehreren von einer axialen Fortsetzung des kräftigen Stieles auseinanderweichen, in Verbindung mit der derben lederartigen Konsistenz des ganzen Körpers und dem kräftig entwickelten, an *Stannophyllum zonarium* erinnernden Linellensystem für ausreichend, um einen besonderen Speziesbegriff, *Stannophyllum alatum*, gleichwertig den übrigen von Haeckel innerhalb der Gattung *Stannophyllum* aufgestellten Arten anzunehmen. Hierbei ist freilich festzuhalten, dass sämtliche bisher unterschiedenen *Stannophyllum*-Arten

keine prägnanten und scharfen Unterschiede aufweisen, sondern miteinander durch mannigfache Übergänge verbunden sind, wie schon früher mehrfach von Haeckel und mir hervorgehoben ist.

Übrigens will ich noch betonen, dass bei den Stücken der Albatross-Expedition 1904/05, welche ich zu *Stannophyllum* rechnen muss, entweder eine so deutlich ausgeprägte quere Endabstutzung des kurzen dicken Stieles vorkommt, dass man ein Abreissen von einer ziemlich ebenen Unterlage anzunehmen veranlasst ist, oder dass eine lockere Linellenschopfbildung besteht. In beiden Fällen haften zahlreiche grössere Foraminiferenschalen diesem basalen Stumpf oder Schopf an; was hier umso mehr auffällt, als die *Xenophya* des ganzen übrigen Körpers fast ausschliesslich aus Radiolarienskeletten besteht.

Stannophyllum alatum Hkl. ist von der Albatross-Expedition nur in drei Exemplaren an der *einen* Station 4742 — 0° 3.4′ N.; 117° 15.8′ W. — 4243 m. tief gefunden.

Die folgende Tabelle gibt Auskunft über die sämtlichen Xenophyophoren-Funde der Albatross-Expedition 1904/5.

Von den 146 Fangstationen dieser Expedition, welche mir wegen ausreichender Tiefe des Meeresgrundes (d. h. unter 500 fathoms = 915 m.) überhaupt für Xenophyophoren inbetracht zu kommen scheinen, ergaben demnach 10 Stationen, also ca. 15% solche Rhizopoden. Diese Fundorte liegen sämtlich zwischen dem 12. Grad südlicher und dem ersten Grad nördlicher Breite, sowie zwischen dem 81. Grad und 118. Grad westlicher Länge. Die Bodentiefe beträgt im allgemeinen ca. 4000 m., nur an einer Station (4653) 981 m.

Für alle Fundorte ist *Schlammgrund* notiert.

Hinsichtlich der Häufigkeit der verschiedenen Spezies ist bemerkenswert, dass *Stannophyllum zonarium* Hkl. an allen diesen Fundorten und zwar grösstenteils in reichlicher Menge erbeutet ist. Auch *Stannophyllum globigerinum* Hkl. und *Stannoma dendroides* Hkl. kamen ziemlich häufig vor (an 4 von den 10 Stationen), während *Stannoma coralloides* und *Stannophyllum alatum* sich nur an je einer der betreffenden Stationen fanden.

Da durch die hier mitgeteilten Ergebnisse der Albatross-Expedition 1904/05 und durch die unlängst von mir veröffentlichten Xenophyophoren-Funde der holländischen Siboga-Expeditie (Lieferung IV bis) unsere Kenntnis von der geographischen Verbreitung der Xenophyophoren nicht unerheblich gewonnen hat, und da auch die von Goës bearbeiteten Xenophyophoren-Funde der Albatross-Expedition vom Jahre 1891 in jenen Zusammenstellungen noch keine Aufnahme gefunden hatten, welche ich

Station.	Position.		Tiefe in Meter.	*Stannoma dendroides* Hkl.	*Stannoma coralloides* Hkl.	*Stannophyllum zonarium* Hkl.	*Stannophyllum globigerinum* Hkl.	*Stannophyllum alatum* Hkl.
	Breite.	Länge.						
	° ′	° ′						
4647	4 33 S.	87 42.5 W.	3667	. . . . . .	. . . . . .	*Stannophyllum zonarium*	*Stannophyllum globigerinum*	
4649	5 17 S.	85 19.5 W.	4090	*Stannoma dendroides*	. . . . . .	*Stannophyllum zonarium*		
4651	5 41 S.	82 59.7 W.	4066	. . . . . .	. . . . . .	*Stannophyllum zonarium*		
4653	5 47 S.	81 24 W.	981	. . . . . .	. . . . . .	*Stannophyllum zonarium*		
4656	6 54.6 S.	83 34.3 W.	4066	. . . . . .	. . . . . .	*Stannophyllum zonarium*		
4658	8 29.5 S.	85 35.6 W.	4334	. . . . . .	. . . . . .	*Stannophyllum zonarium*		
4666	11 55 S.	84 20.3 W.	4755	. . . . . .	. . . . . .	*Stannophyllum zonarium*		
4717	5 10 S.	98 56 W.	3937	*Stannoma dendroides*	. . . . . .	*Stannophyllum zonarium*	*Stannophyllum globigerinum*	
4721	8 7.5 S.	104 10.5 W.	3814	*Stannoma dendroides*	. . . . . .	*Stannophyllum zonarium*	*Stannophyllum globigerinum*	
4742	0 3.4 N.	117 15.8 W.	4243	*Stannoma dendroides*	*Stannoma coralloides*	*Stannophyllum zonarium*	*Stannophyllum globigerinum*	*Stannophyllum alatum*

im Jahre 1905 in meiner Monographie der Xenophyophoren gegeben hatte, so lasse ich hier eine Übersicht aller bisher bekannt gewordenen Fundorte von Xenophyophoren folgen, mit Angabe der Bodentiefe und der betreffenden Station der inbetracht kommenden Expeditionen.

I. ATLANTIK.

Position.						Tiefe in Meter.	Expedition Station.
Breite.			Länge.				
°	′		°	′			
38	25	N.	35	50	W.	3065	Chall. 70
22	18	N.	22	2	W.	4392	Chall. 89
37	47	S.	30	20	W.	3138	Chall. 331

II. INDIK.

Position.						Tiefe in Meter.	Expedition Station.
Breite.			Länge.				
°	′		°	′			
1	47.8	S.	41	45.8	O.	1668	Vald. 250
4	50.5	S.	127	59	O.	2081	Siboga 227
5	40.7	S.	120	45.5	O.	1158	Siboga 211
6	12.9	S.	41	17.3	O.	2959	Vald. 240
6	24	S.	124	39	O.	2798	Siboga 221
10	35.6	S.	124	11.7	O.	2050	Siboga 295

III. PAZIFIK.

Position.						Tiefe in Meter.	Expedition Station.
Breite.			Länge.				
°	′		°	′			
35	41	N.	157	42	O.	4209	Chall. 241
35	22	N.	169	53	O.	5307	Chall. 244
14	46	N.	98	40	W.	3344	Alb. 3415
10	14	N.	96	28	W.	3972	Alb. 3414
2	56	N.	134	11	O.	3660	Chall. 216 A.
2	55	N.	124	53	W.	3935	Chall. 198
1	7	N.	8	4	W.	3097	Alb. 3399
0	50	N.	137	54	W.	4507	Alb. 3684 (17[1])
0	3.4	N.	117	15.8	W.	4243	Alb. 4742
0	33	S.	151	34	W.	4438	Chall. 271

[1] In meiner Monographie (im Jahre 1905) als Albatross-Station 17 aufgeführt.

III. PAZIFIC, *Continued.*

Position.		Tiefe in Meter.	Expedition Station.
Breite.	Länge.		
° ′	° ′		
0 42 S.	147 0 O.	2013	Chall. 220
2 34 S.	149 9 W.	5353	Chall. 270
3 48 S.	152 56 W.	4758	Chall. 272
4 33 S.	87 42.5 W.	3667	Alb. 4647
5 10 S.	98 56 W.	3937	Alb. 4717
5 17 S.	85 19.5 W.	4090	Alb. 4649
5 41 S.	82 59.7 W.	4066	Alb. 4651
5 47 S.	81 24 W.	981	Alb. 4653
6 54.6 S.	83 34.3 W.	4066	Alb. 4656
7 25 S.	152 15 W.	5033	Chall. 274
8 7.5 S.	104 10.5 W.	3814	Alb. 4721
8 29.5 S.	85 35.6 W.	4334	Alb. 4658
11 55 S.	84 20.3 W.	4755	Alb. 4666
39 22 S.	98 46 W.	4154	Chall. 294

Von den 33 jetzt bekannten Fundorten gehören demnach 3 dem Gebiete des *atlantischen*, 6 dem des *indischen* und 24 dem des *stillen* Ozeans an.

Sämtliche Fundorte liegen zwischen 40° nördlicher und 40° südlicher Breite. Die meisten finden sich in der Nähe des Äquators, d. h. zwischen 10° nördlicher und 10° südlicher Breite. Nur ganz wenige liegen ausserhalb der Tropen, nämlich drei nördlich vom nördlichen und zwei südlich vom südlichen Wendekreis.

Auf der hier folgenden kleinen Karte werden diese Verhältnisse zu unmittelbarer Anschauung gebracht durch die roten Zeichen, bei welchen durch die Zahl der Zacken die Anzahl der an ein und demselben Orte gefundenen Spezies angegeben ist, während ein kreisrunder Fleck den Ort bezeichnet, wo nur *eine* Spezies erhalten ist.

Eine Anordnung der 33 Fundorte nach der Bodentiefe ergibt folgende Tabelle:

BATHYMETRISCHE VERBREITUNG DER XENOPHYOPHOREN.

Tiefe in Meter.	Expedition Station.	Position.		Spezies.
		Breite.	Länge.	
		° ′	° ′	
981	Albatros 4653	5 47 S.	81 24 W.	*Stannophyllum zonarium* Hkl.
1158	Siboga 211 . .	5 40.7 S.	120 45.5 O.	*Psammetta globosa* F. E. Sch., *Psammina globigerina* Hkl., *Stannophyllum globigerinum* Hkl.

BATHYMETRISCHE VERBREITUNG DER XENOPHYOPHOREN.

Continued.

Tiefe in Meter.	Expedition Station.	Position. Breite.			Position. Länge.			Spezies.
		°	′		°	′		
1668	Valdivia 250 .	1	47.8	S.	41	58.8	O.	*Psammetta erythrocytomorpha* F. E. Sch.
2013	Challenger 220	0	42	S.	147	0	O.	*Psammina globigerina* Hkl.
2050	Sib. 295 . . .	10	35.6	S.	124	11.7	O.	*Psammophyllum globigerinum* Hkl.
2081	Sib. 227 . . .	4	50.5	S.	127	59	O.	*Psammina globigerina* Hkl.
2798	Sib. 221 . . .	6	24	S.	124	39	O.	*Stannophyllum globigerinum* Hkl.
2959	Vald. 240 . .	6	12.9	S.	41	17.3	O.	*Stannophyllum globigerinum* Hkl.
3065	Chall. 70 . .	38	25	N.	35	50	W.	*Holopsamma cretaceum* Hkl.
3097	Alb. 3399 . .	1	7	N.	8	4	W.	*Stannophyllum zonarium* Hkl.
3138	Chall. 331 . .	37	47	S.	30	20	W.	*Psammina plakina* Hkl.
3344	Alb. 3415 . .	14	46	N.	98	40	W.	*Stannophyllum zonarium* Hkl.
3660	Chall. 216 A .	2	56	N.	134	11	O.	*Cerellasma lamellosa* Hkl.
3667	Alb. 4647 . .	4	33	S.	87	42.5	W.	*Stannophyllum zonarium* Hkl., *Stannophyllum globigerinum* Hkl.
3814	Alb. 4721 . .	8	7.5	S.	104	10.5	W.	*Stannoma dendroides* Hkl., *Stannophyllum zonarium* Hkl., *Stannophyllum globigerinum* Hkl.
3935	Chall. 198 . .	2	55	N.	124	53	W.	*Stannophyllum reticulatum* Hkl.
3937	Alb. 4717 . .	5	10	S.	98	56	W.	*Stannoma dendroides* Hkl., *Stannophyllum zonarium* Hkl., *Stannophyllum globigerinum* Hkl.
3972	Alb. 3414 . .	10	14	N.	96	28	W.	*Stannophyllum zonarium* Hkl.
4066	Alb. 4651 . .	5	41	S.	82	59.7	W.	*Stannophyllum zonarium* Hkl.
4066	Alb· 4656 . .	6	54.6	S.	83	34.3	W.	*Stannophyllum zonarium* Hkl.
4090	Alb. 4649 . .	5	17	S.	85	19.5	W.	*Stannoma dendroides* Hkl., *Stannophyllum zonarium* Hkl.
4154	Chall. 294 . .	39	22	S.	98	46	W.	*Holopsamma argillaceum* Hkl.
4209	Chall. 241 . .	35	41	N.	157	42	O.	*Stannophyllum flustraceum* Hkl.
4243	Alb. 4742 . .	0	3.4	N.	117	15.8	W.	*Stannoma dendroides* Hkl., *Stannoma coralloides* Hkl., *Stannophyllum zonarium* Hkl., *Stannophyllum globigerinum* Hkl., *Stannophyllum alatum* Hkl.
4334	Alb. 4658 . .	8	29.5	S.	85	35.6	W.	*Stannophyllum zonarium* Hkl.
4892	Chall. 89 . .	22	18	N.	22	2	W.	*Psammopemma calcareum* Hkl.
4438	Chall. 271 . .	0	33	S.	151	34	W.	*Cerelasma gyrosphaera* Hkl., *Stannoma dendroides* Hkl., *Stannoma coralloides* Hkl., *Stannophyllum zonarium* Hkl., *Stannophyllum radiolarium* Hkl., *Stannophyllum pertusum* Hkl., *Stannophyllum venosum* Hkl., *Stannophyllum globigerinum* Hkl.
4507	Alb. 3684 (17[1])	0	50	N.	137	54	W.	*Stannoma dendroides* Hkl., *Stannoma coralloides* Hkl., *Stannophyllum zonarium* Hkl., *Stannophyllum globigerinum* Hkl.
4755	Alb. 4666 . .	11	55	S.	84	20.3	W.	*Stannophyllum zonarium* Hkl.
4758	Chall. 272 . .	3	48	S.	152	56	W.	*Psammopemma radiolarium* Hkl., *Stannoma dendroides* Hkl., *Stannophyllum alatum* Hkl.
5033	Chall. 274 . .	7	25	S.	152	15	W.	*Psammina nummulina* Hkl.
5307	Chall. 244 . .	35	22	N.	169	53	O.	*Stannophyllum annectens* Hkl.
5353	Chall. 270 . .	2	34	S.	149	9	W.	*Stannarium concretum* Hkl.

[1] In meiner Monographie (im Jahre 1905) als Albatross-Station 17 aufgeführt.

Man sieht, dass von den 33 bekannten Fundorten 27, also fast 82%, zwischen 2000 und 5000 m. Tiefe haben und dass von diesen wieder 12 Fundstellen, also nahezu 34% der ganzen Reihe, zwischen 4000 und 5000 m. tief sind.

Nur 3 Fundorte bleiben oberhalb 2000 m., und von diesen erreicht eine sogar (mit 981 m.) noch nicht einmal 1000 m.

Von den drei unter 5000 m. tiefen Fundorten geht der tiefste bis zu 5353 m. hinab.

Ein Einfluss der Bodentiefe auf die Verbreitung der einzelnen systematischen Gruppen lässt sich nicht erkennen. Weder die beiden Familien der Psamminiden und Stannomiden, noch die einzelnen Gattungen zeigen eine deutliche Abhängigkeit ihres Vorkommens von der Bodentiefe. Höchstens könnte man hervorheben, dass die Gattung *Psammetta* bisher nur oberhalb 2000 m. gefunden ist.

Einzelne Spezies, wie z. B. *Stannophyllum zonarium* Hkl., kommen in sehr verschiedenen Tiefen vor — von 981 bis 4755 m.

Zum Schluss gebe ich eine nach dem Zoolog. System geordnete Übersicht der Fundorte aller bisher bekannt gewordenen Xenophyophoren-Spezies.

Es sind also bisher die Stannomiden in weiterer Verbreitung gefunden als die Psamminiden und speziell einige Arten, wie *Stannoma dendroides* Hkl., *Stannophyllum zonarium* Hkl., und *Stannophyllum globigerinum* Hkl., besonders reichlich im östlichen Teile des tropischen Pazifik.

Die Psamminiden scheinen mehr dem Indischen Ozean und speziell dem Gebiete der Sunda-Inseln anzugehören.

NACH DEM SYSTEM GEORDNET.

	Expedition Station.	Position.		Tiefe in Meter.
		Breite.	Länge.	
A. Psamminidae F. E. Sch.				
I. *Psammetta* F. E. Sch.		° ′	° ′	
1. *Ps. globosa* F. E. Sch.	Siboga 211	5 40.7 S.	120 45.5 O.	1158
2. *Ps. erythrocytomorpha* F. E. Sch.	Valdivia 250	1 47.8 S.	41 58.8 O.	1668
II. *Psammina* Hkl.				
1. *Ps. plakina* Hkl.	Chall. 331	37 47.0 S.	30 20.0 W.	3138
2. *Ps. globigerina* Hkl.	Chall. 220	0 42.0 S.	147 0.0 O.	2013
	Siboga 211	5 40.7 S.	120 45.5 O.	1158
	Siboga 227	4 50.5 S.	127 59.0 O.	2081
3. *Ps. nummulina* Hkl.	Chall. 274	7 25.0 S.	152 15.0 W.	5033
III. *Cerelasma* Hkl.				
1. *C. gyrosphaera* Hkl.	Chall. 271	0 33.0 S.	151 34.0 W.	4438
2. *C. lamellosa* Hkl.	Chall. 216 A	2 56.0 N.	134 11.0 O.	3660

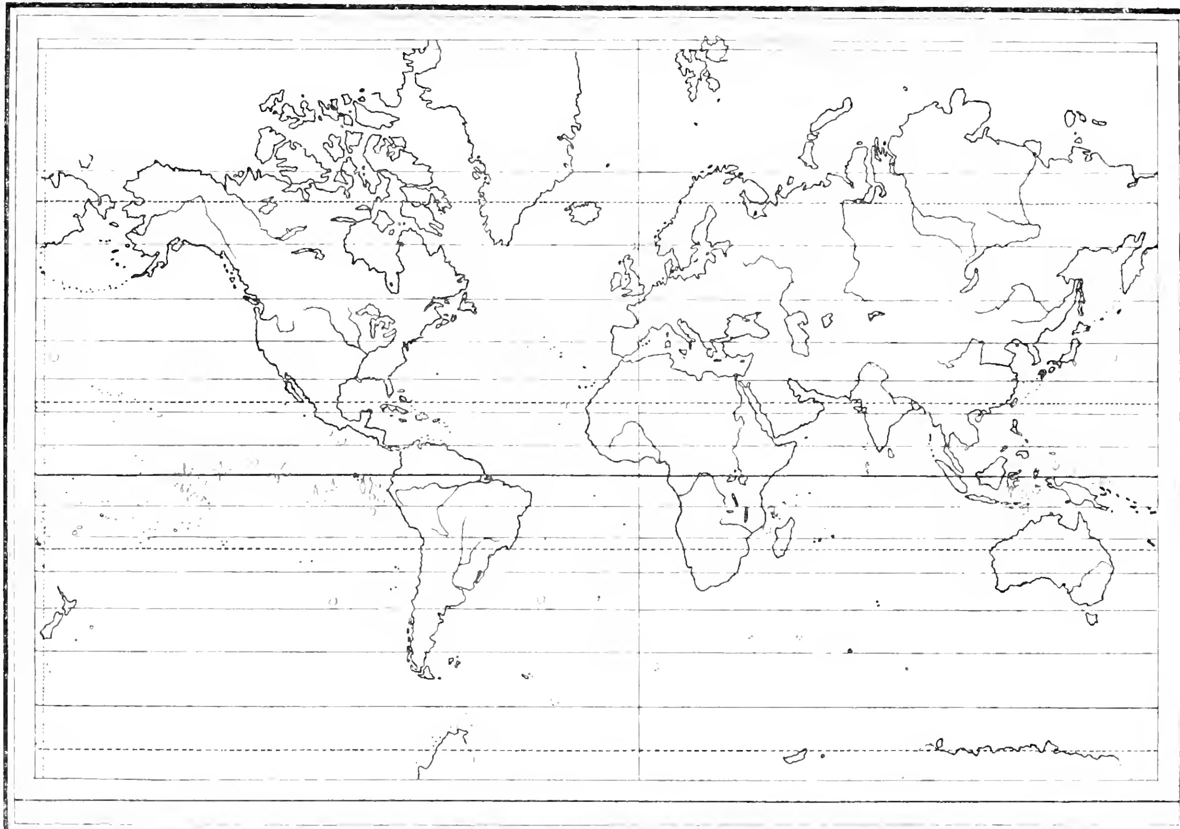
NACH DEM SYSTEM GEORDNET, *Continued.*

	Expedition Station.	Position.		Tiefe in Meter.
		Breite.	Länge.	
		° ′	° ′	
IV. *Holopsamma* Carter				
1. *H. cretaceum* Hkl.	Chall. 70	38 25.0 N.	35 50.0 W.	3065
2. *H. argillaceum* Hkl.	Chall. 294	39 22.0 S.	98 46.0 W.	4154
V. *Psammopemma* Marshall				
1. *Ps. radiolarium* Hkl.	Chall. 272	3 48.0 S.	152 56.0 W.	4758
2. *Ps. calcareum* Hkl.	Chall. 89	22 18.0 N.	22 2.0 W.	4392
B. Stannomidae F. E. Sch.				
I. *Stannoma* Hkl.				
1. *St. dendroides* Hkl.	Chall. 271	0 33.0 S.	151 34.0 W.	4438
	Chall. 272	3 48.0 S.	152 56.0 W.	4758
	Alb. 3684 (17[1])	0 50.0 N.	137 54.0 W.	4507
	Alb. 4649	5 17.0 S.	85 19.5 W.	4090
	Alb. 4717	5 10.0 S.	98 56.0 W.	3937
	Alb. 4721	8 7.5 S.	104 10.5 W.	3814
	Alb. 4742	0 3.4 N.	117 15.8 W.	4243
2. *St. coralloides* Hkl.	Chall. 271	0 33.0 S.	151 34.0 W.	4438
	Chall. 272	3 48.0 S.	152 56.0 W.	4758
	Alb. 3684 (17[1])	0 50.0 N.	137 54.0 W.	4507
	Alb. 4742	0 3.4 N.	117 15.8 W.	4243
II. *Stannophyllum* Hkl.				
1. *St. zonarium* Hkl.	Chall. 271	0 33.0 S.	151 34.0 W.	4438
	Alb. 3299	1 7.0 N.	81 4.0 W.	3097
	Alb. 3414	10 14.0 N.	96 28.0 W.	3972
	Alb. 3415	14 46.0 N.	98 40.0 W.	3415
	Alb. 3684 (17[1])	0 50.0 N.	137 54.0 W.	4507
	Alb. 4647	4 33.0 S.	87 42.5 W.	3667
	Alb. 4649	5 17.0 S.	85 19.5 W.	4090
	Alb. 4651	5 41.0 S.	82 59.7 W.	4066
	Alb. 4653	5 47.0 S.	81 24.0 W.	981
	Alb. 4656	6 54.6 S.	83 34.3 W.	4066
	Alb. 4658	8 29.5 S.	85 35 6 W.	4334
	Alb. 4666	11 55.0 S.	84 20.3 W.	4755
	Alb. 4717	5 10.0 S.	98 56.0 W.	3937
	Alb. 4721	8 7.5 S.	104 10.5 W.	3814
	Alb. 4742	0 3.4 N.	117 15.8 W.	4243
2. *St. radiolarium* Hkl.	Chall. 271	0 33.0 S.	151 34.0 W.	4438
3. *St. pertusum* Hkl.	Chall. 271	0 33.0 S.	151 34.0 W.	4438
4. *St. venosum* Hkl.	Chall. 271	0 33.0 S.	151 34.0 W.	4438
5. *St. globigerinum* Hkl.	Chall. 271	0 33.0 S.	151 34.0 W.	4438
	Alb. 3684 (17[1])	0 50.0 N.	137 54 0 W.	4507
	Valdivia 240	6 12.9 S.	41 17.3 O.	2959
	Siboga 211	5 40.7 S.	120 45.5 O.	1158
	Siboga 221	6 24.0 S.	124 39.0 O.	2798
	Siboga 295	10 35.6 S.	124 11.7 O.	2050
	Alb. 4647	4 33.0 S.	87 42.5 W.	3667
	Alb. 4717	5 10.0 S.	98 56.0 W.	3937
	Alb. 4721	8 7.5 S.	104 10.5 W.	3814
	Alb 4742	0 3.4 N.	117 15.8 W.	4243
6. *St. reticulatum* Hkl.	Chall. 198	2 55.0 N.	124 53.0 W.	3935
7. *St. flustraceum* Hkl.	Chall. 241	35 41.0 N.	157 42.0 O.	4209
8. *St. annectens* Hkl.	Chall. 244	35 22.0 N.	169 53 0 O.	5307
9. St. *alatum* Hkl.	Chall. 272	3 48.0 S.	152 56.0 W.	4758
	Alb. 4742	0 3.4 N.	117 15.8 W.	4243
III. *Stannarium* Hkl.				
St. concretum Hkl.	Chall. 270	2 34.0 S.	149 9.0 W.	5353

[1] In meiner Monographie (im Jahre 1905) als Albatross-Station 17 aufgeführt.

TAFEL.

Fundorte von Xenophyophoren.



Fundorte von Xenophyophoren.

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THE CIDARIDAE.

By Hubert Lyman Clark.

With Eleven Plates.

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No. 7. — *The Cidaridae.* By Hubert Lyman Clark.

Introduction.

The opening years of the present century have witnessed the publication of an unusual number of quarto volumes dealing with the morphology and classification of the Echini. In each of these the Cidaridae receive considerable attention, and many genera of that family, new either in name or in contents, are proposed. As the different writers reveal wide divergence of opinion as to the relative importance of the characters on which the classification of the Echini is based, the arrangement of the Cidaridae differs to an unusual degree in these several reports. Mortensen (**:03**)[1] practically rejects previous classifications and the principles on which they are based, and, ignoring the fossil forms, to which his method is not applicable, recognizes thirteen genera and a subgenus, defined wholly in terms of the pedicellariae, the spicules of the pedicels, and occasionally the spines. It is only fair to state, however, that the writer says frankly, these features are not "sufficient for definitive diagnoses." He includes in his classification 42 species, and lists 12 others which he is unable to place satisfactorily because of lack of information about the pedicellariae. Very soon after this volume appeared, de Meijere's (**:04**)[2] valuable report on the "Siboga" Echini was published. Unwilling to accept Mortensen's genera unreservedly, the writer adopts the clumsy and unsatisfactory method of recognizing only a single genus, Cidaris, and using Mortensen's names for subgenera. Later in the same year Agassiz (**:04**)[3] in his report on the Panamic deep-sea Echini, points out the weaknesses of Mortensen's method and the unsatisfactory nature of his results, and emphasizes anew the great morphological significance of the test (including the abactinal system). Two years

[1] The Danish Ingolf-Expedition, **4**, 1. Echinoidea. Part 1. Th. Mortensen. Translated by Torben Lundbeck. 193 pp., 21 pls. Copenhagen, 1903.

[2] Die Echinoidea der Siboga-Expedition. J. C. H. de Meijere. 252 pp., 23 pls. Leiden, 1904.

[3] The Panamic Deep Sea Echini. Alexander Agassiz. Mem. Mus. Comp. Zoöl., **31**, 243 pp., 112 pls. 1904.

later Döderlein (:06),[1] in an effort to avoid some of the difficulties of Mortensen's system, and yet to retain the valuable results of his work, offers a classification of the recent Cidaridae, consisting of ten genera and five subgenera, defined chiefly in terms of the pedicellariae. This classification, however, is quite different from any of its predecessors because, while Döderlein attempts to apply rigidly the recent International Code of zoölogical nomenclature, his interpretation of certain perplexing cases is quite different from either Mortensen's or Agassiz's. Finally Agassiz and Clark (:07)[2] reject the proposed innovations of both Mortensen and Döderlein and offer considerable evidence in support of their view that the pedicellariae of the Cidaridae are as unreliable for generic characters as are the spines.

It is perfectly obvious, therefore, that the classification of the Cidaridae is at the present time in a state of great confusion, and that some effort should be made to reduce it to order and place it on a permanent basis. Thanks to the great kindness of Mr. Agassiz, a very unusual amount of material, both recent and fossil, has been accessible to me during the past two years, and I have endeavored to find and formulate a natural arrangement of the Cidaridae. Needless to say, Mr. Agassiz is not responsible in any way for statements made or opinions expressed in the following pages, but whatever value my results may have are due to his constant sympathy and encouragement, and I wish here, in this inadequate way, to express my thanks to him. I have also to thank Dr. Richard Rathbun for the privilege of examining the collection of Cidaridae in the United States National Museum, and this proved to be of added interest because it has recently been studied by Dr. Mortensen, who, in many cases, left labels in his own hand, showing the views he held as to the identification of the specimens. As my point of view differs fundamentally from his, I desire to do him full justice, and the examination of a collection, a large part of which has been named by him, was therefore of special importance to me. Finally I may add that in the preparation of this report I have personally handled not less than 3,100 specimens, representing 48 of the 60 recent species which appear to me to be valid, and all of the 15 recent genera herein recognized.

[1] Die Echinoiden der deutschen Tiefsee-Expedition. Ludwig Döderlein. 290 pp., 42 pls. Jena, 1906.

[2] Hawaiian and other Pacific Echini. The Cidaridae. Alexander Agassiz and Hubert Lyman Clark. Mem. Mus. Comp. Zoöl., **34**, 42 pp., 44 pls. 1907.

Historical summary.

The first writer to use the name Cidaris for a genus of Echini was Klein (**1734**), who, however, included all of the regular sea-urchins under that name. Linné (**1758**) used the same name for a *species* of Echinus, but Leske (**1778**) was the first writer subsequent to Klein who recognized Cidaris as a genus. Only one of the 28 species which he includes in the genus belongs in the family Cidaridae as understood to-day, and to that one he gave the name *papillata*. Now it is clear from both text and figures that Leske intended to include under the name "*Cidaris papillata*" all those regular Echini with the conspicuous interambulacral tubercles of the Cidaridae. His "species" is therefore a composite group, including not only the now well-known European *Dorocidaris papillata*, but also *Phyllacanthus imperialis* and several species of the restricted genus Cidaris, one of which appears to have been *tribuloides* Lamarck. The next writer to deal with the classification of the Echini was Lamarck (**'16**), and he clearly indicates and defines the group which we now call the Cidaridae. He called them "Turbans," under his genus Cidarites. So far as the Cidaridae are concerned the name Cidarites is equivalent to Leske's *Cidaris papillata* and is obviously a synonym of Cidaris. It cannot be used, therefore, at the present time for any genus of animals. Lamarck listed eleven species of "Turbans," all but one of which were recognized and described by Alexander Agassiz in 1872, in his classic "Revision of the Echini." No attempt to subdivide the genus Cidaris was made until 1835, when Brandt established the genus Phyllacanthus for a supposedly new species, *dubia*. He divided Lamarck's Cidarites into two sections, A (including the species not in B and for which he selected and named *tribuloides* Lam. as the type species) and B, Phyllacanthus, with *dubia* for the type, and including also *imperialis*, *hystrix*, *geranioides*, and *pistillaris*. Later investigation made it plain that of these four only *imperialis* and *pistillaris* are congeneric with *dubia*, and the other two were therefore returned to Cidaris. In 1872 A. Agassiz showed, however, that Lamarck's *baculosa*, *verticillata*, and *annulifera* had important features in common with *dubia* and *imperialis* and accordingly placed them in Phyllacanthus. When Agassiz and Desor (**'46**) considered the Cidaridae, they neglected Phyllacanthus, but established Goniocidaris with *geranioides* for the type, and with it associated a "new" species *quoyi*, which subsequently proved to be synonymous with Lamarck's *tubaria*. In 1851 Desor suggested as genera of fossil Cidaridae, Rhabdocidaris, Diplocidaris, Porocidaris, and Leiocidaris, and in

1858 he described the fossil Eocidaris. The same year (1858) Quenstedt named Polycidaris and Leptocidaris for fossil forms. In 1862 Cotteau described the remarkable fossil Orthocidaris, and the following year the equally interesting fossil Temnocidaris. In 1863, A. Agassiz suggested the name Stephanocidaris for Lamarck's *bispinosa*, and Prionocidaris for *pistillaris*. At the same time he proposed Chondrocidaris as a new genus for a notable species from the Hawaiian Islands, and Gymnocidaris for *metularia* Lam. and a supposedly new species, *minor*. He also proposed Orthocidaris and Temnocidaris as new genera of recent Cidaridae, but later (1869) withdrew them as preoccupied by Cotteau's fossil forms. At this later date he suggested Dorocidaris for a new species, *abyssicola*, associating with it *affinis* Phil. and *papillata* Leske. With the last Lamarck's *hystrix* is synonymous, and consequently, as a result of these various changes, there remained in Lamarck's genus "Cidarites: Turbans" only the well-known West Indian species, *tribuloides*.

In the "Revision of the Echini" (1872) A. Agassiz recognized only six genera of the recent Cidaridae, as follows: —

Cidaris Klein, with 3 species. (Including Gymnocidaris A. Ag.)
Dorocidaris A. Agassiz, with 1 species. (Including Orthocidaris A. Ag.)
Phyllacanthus Brandt, with 6 species. (Including Prionocidaris A. Ag., and Chondrocidaris A. Ag.)
Stephanocidaris A. Agassiz, with 1 species.
Porocidaris Desor, with 1 species.
Goniocidaris Desor, with 3 species. (Including Temnocidaris A. Ag.)

This classification has been maintained by Agassiz ever since, without any changes other than the addition of ten more species (1881, 1883, 1898) and the unique genus Centrocidaris (1904).

In 1877 Studer described Schleinitzia as a recent genus allied to Phyllacanthus. In 1883 Pomel divided the "Cidaridés" into three subfamilies, the Cidariens, Goniocidariens, and Rhabdocidariens. The first contains four genera, including of Agassiz's six only Cidaris, which is divided into five sections (subgenera ?); the second subfamily contains four genera also, including Dorocidaris and Goniocidaris of Agassiz's list; the third contains seven genera, including the remaining three of Agassiz, though Stephanocidaris is considered only a subgenus (?) of Phyllacanthus. Although Pomel thus recognizes fifteen genera and six subgenera (?), his classification of the recent forms is essentially identical with that of A. Agassiz. The new genera which he proposes are Tylocidaris, Stereocidaris, Typocidaris, and Pleurocidaris, all for fossil

forms. His proposed subgenera of Cidaris are, Plegiocidaris, Paracidaris, Procidaris, Polycidaris, and Eucidaris. In 1884 Zittel proposed Anaulocidaris for a fossil cidaroid, and in 1885 Döderlein used the name Discocidaris for some recent Japanese species. In 1887 Döderlein published a classification of the Cidaridae, including the fossil as well as the recent forms. Of the 22 genera which he recognizes, 15 include only fossil species. He rejects Stephanocidaris altogether, and uses Desor's name Leiocidaris for Phyllacanthus. For some inexplicable reason he considers *Porocidaris sharreri* A. Ag. as a living representative of Pomel's genus Pleurocidaris. To another of Pomel's genera, Stereocidaris, he assigns three recent Japanese species which he describes. He proposes four new genera of fossil cidaroids, but only gives names to three: Mikrocidaris, Triadocidaris, and Miocidaris. In 1889 Duncan's "Revision of the Genera . . . of the Echinoidea" appeared, with a classification of the Cidaridae, which at first sight seems unique, but on examination proves to be novel only in the rank assigned to the different groups. The writer divides the family into two sections, of which the first contains four genera and one subgenus, and the second contains two genera. For recent forms only the genus Cidaris, with a subgenus Goniocidaris, is allowed, but the heterogeneous nature of such a genus is so far acknowledged that it is divided into seven "divisions," of which five contain the recent species. These five "divisions" with the subgenus Goniocidaris correspond in name and contents to the genera maintained by A. Agassiz. In 1902 Lambert proposed for certain fossil and recent Cidaridae previously referred to Stereocidaris, the name Phalacrocidaris, and in 1903 he suggested for some fossil species allied to Phyllacanthus, the name Aulacocidaris.

In 1903 Mortensen entirely rearranged the recent species of the family, uniting or separating them according to resemblances or differences in the large globiferous pedicellariae. In this way he makes thirteen genera and a subgenus, and although he uses the names of the six genera of A. Agassiz, the grouping of the species is wholly different from that writer's. Mortensen's classification is as follows: —

Dorocidaris A. Ag. (emend.), 4 species.
Tretocidaris, g. n., 3 species.
Stephanocidaris A. Ag. (emend.), 3 species.
Schizocidaris, g. n., 1 species.
Cidaris Klein (emend.), 8 species.
Chondrocidaris A. Ag., 1 species.
Acanthocidaris, g. n., 1 species.

Stereocidaris Pomel, 10 species.
Goniocidaris Desor, 4 species and subgenus Discocidaris Döderlein, 3 species.
Petalocidaris, g. n., 1 species.
Phyllacanthus Brandt (emend.), 3 species.
Histocidaris, g. n., 1 species.
Porocidaris Desor, 1 species and 1 variety.
Genus undetermined, 12 species.
Total, 56 species and 1 variety.

Of these 56 species, seven, and the one variety, are described for the first time, but only one of them is figured. Unfortunately Mortensen was handicapped by lack of material and the apparent necessity of not denuding even in part the specimens which were available, and as a consequence his descriptions are, with one exception, incomplete, and in several cases quite inadequate. Good photographs of his types would be a very great help in recognizing these supposedly new species.

In 1906 Döderlein presents his classification of the recent Cidaridae, the result of more than twenty years' study of the family. It is radically different from his earlier (1887) arrangement, not merely because no reference is made to fossil forms, but because he endeavors to make use of Mortensen's principles, which his own observations often contradict[1] and his judgment not infrequently condemns.[2] This latest arrangement of the family is as follows: —

Cidaris Leske (syn. Dorocidaris A. Ag.), 4 species.
Tretocidaris Mortensen, 3 species.
Cidarites Lamarck (syn. Cidaris emend. Mortensen).
Subgenus Dorocidaris A. Ag., 4 species.
Gymnocidaris A. Ag., 3 species and 1 variety.
Stephanocidaris A. Ag., 5 species and 7 varieties.
Chondrocidaris A. Ag., 1 species.
Goniocidaris L. Agassiz et Desor.
Subgenus Goniocidaris s. str., 6 species.
Discocidaris Död., 6 species.
Stereocidaris Pomel, 14 species.
Acanthocidaris Mortensen, 1 species.
Phyllacanthus Brandt, 1 species and 3 varieties.
Histocidaris Mortensen, 2 species.
Porocidaris Desor, 1 species and 1 variety.
Genus undetermined, 6 species.
Total: 10 genera, 5 subgenera, 57 species, and 12 varieties.

1 Compare page 102, line 24, with page 106, lines 34–36 and page 109, lines 20–21.
2 See p. 93 *et seq.*

In 1907 A. Agassiz and Clark published descriptions and numerous figures of nine new species of Cidaridae and instituted two new genera, Anomocidaris and Aporocidaris. They also furnished much additional information concerning Stephanocidaris, Centrocidaris, and Acanthocidaris and in regard to diversity of form in the pedicellariae of the group.

Fundamental Principles for a Natural Classification.

Before attempting to set forth a revised classification of the Cidaridae, if it is hoped to have it stable and generally acceptable, one ought to make plain the principles on which it is based. These principles must take into account not only the characters afforded by the specimens themselves and the proper estimation of the relative value of these, but also the selection of names for the genera and species held to be valid. Fortunately there is coming to be more and more general agreement among zoölogists as to the principles which should govern in the selection of names, and the very general acceptance of the International Code of Nomenclature, at least in its essentials, indicates clearly the approach of the time when nomenclature will be fixed. In the following pages adherence has been given to the rules of the International Code, but whenever there has been room for difference of opinion as to the application of those rules, that course has been followed which would cause the least possible change from currently accepted names. Consequently there are few changes from the names established or indorsed by A. Agassiz in the "Revision of the Echini" and almost universally used in the last quarter of the nineteenth century. Unfortunately there is no code by which can be determined the relative importance of the various characters which distinguish the different species and genera of Echini. Here each writer is thrown upon his own resources, and his proposed classification will stand or fall according to the judgment he displays in selecting stable and significant characters. The fundamental difficulty with the classification of Mortensen is that it is based almost wholly upon the characters of the pedicellariae alone, and the history of zoölogy shows again and again that a classification based on a single character, however suggestive it may be, is never reliable. The characters afforded by the pedicellariae are important, but those organs are, like all calcareous formations among echinoderms, liable to great diversity. It is of no special importance in this connection whether the pedicellariae are modified spines or not, the only point being whether, like the spines,

they show great individual variability. The evidence offered by A. Agassiz and Clark (:07) cannot be ignored or denied, and we are therefore forced to conclude that neither spines nor pedicellariae can be depended on to furnish unvarying characters. On the other hand, Duncan errs in placing his reliance almost exclusively on the test and in neglecting the characters afforded by the spines and pedicellariae. The classification used by A. Agassiz and the first one proposed by Döderlein ('87) show a judicious balancing of the various characters, and undoubtedly must serve as the basis for the natural classification we are seeking. Döderlein's latest arrangement of the Cidaridae does not appeal to me as being well-balanced, for many excellent characters afforded by the test and spines are neglected or given little weight, while the interesting diversities of the pedicellariae are permitted to outweigh all else. It seems to me there can be little question, either on *a priori* grounds or as a result of observation, that the characters afforded by the test are the most important in determining relationships among the Cidaridae, and that those of the corona appear to be more reliable than those of the abactinal system and actinostome. The size of the two latter as compared with each other and with the size of the test are useful factors in many cases, but there is considerable individual diversity in these proportions. This is true also of the arrangement of the plates of the abactinal system, the position, form, and size of which nevertheless often furnish characters of very great weight. The primary spines reveal obvious and tempting features, but these must be used with caution, they are generally so variable. Curiously enough, however, in certain cases a character afforded by the primaries is very constant, even though in nearly related species the same character may be very variable. The pedicellariae well repay careful examination and often reveal interesting and constant peculiarities, but, as has already been emphasized, they, like the spines, are subject to great individual diversity. Indeed, it seems to be true that a species which has very variable spines is likely to have equally variable pedicellariae. The secondary, and even the miliary, spines sometimes show characters of real value, although in certain cases they are as variable as the primaries. The calcareous particles in the tube-feet seem to be so uniform in the family but so variable, within these limits, in the individual that they afford no real help in classification.

In the classification set forth in the following pages I have attempted to place the proper value on each of the features of Cidaridean anatomy mentioned above, and I have also taken into account geographical and

bathymetrical distribution. Even the suggestions of size, color, habitat, and habits have not been ignored in the effort to learn the real interrelationships of the species. At the suggestion of Mr. Agassiz, I have included the genera of fossil Cidaridae, as well as the recent forms, in order that the result may be as useful to palaeontologists as to zoölogists, and I have endeavored to give special consideration and due weight to those characters upon which palaeontologists are obliged to rely I am forced to the conclusion, however, that in most cases little value attaches to the presence or absence of crenulation on the tubercles, to the straightness or sinuosity of the ambulacra, or to the amount of confluence of the areolae. While these features are frequently very obvious in fossils, experience with large series of specimens shows that they are very variable in individuals of the same species, and the most striking differences may be due to the age or condition of the specimen. Far be it from me to claim that the genera which I have adopted are all of equal value or that they ought to be adopted as herein defined by all future writers. The genera Phyllacanthus and Stereocidaris are notably unsatisfactory, and it is quite likely that they will be entirely rearranged in the light of further knowledge. Perhaps the same is true of Goniocidaris. But it is hoped that the classification and nomenclature set forth in the following pages may be a real step towards the ideal which we seek.

The Genera.

In attempting to apply the principles outlined above, it will be convenient to begin with those genera which are accepted by A. Agassiz, Döderlein, Mortensen, and Pomel, and virtually by Duncan also. These genera are: —

Cidaris Leske.	Porocidaris Desor.
Goniocidaris L. Agassiz et Desor.	Phyllacanthus Brandt.

Döderlein (:06) has reached the very disturbing conclusion that *papillata* is the type of Cidaris, and that consequently Dorocidaris A. Ag. is a synonym of Cidaris Leske. Acting on this belief, he has introduced Lamarck's name Cidarites for Cidaris as commonly used, and divides it into three subgenera, to one of which he applies the name Dorocidaris A. Ag. In doing this, Döderlein overlooks the very important fact that Leske's *Cidaris papillata* is a composite group which was first broken up by Lamarck. It includes at least three species, — *imperialis*, which Brandt removed to Phyllacanthus; *papillata*, which

A. Agassiz removed to Dorocidaris; and *tribuloides* (or possibly *metularia*; it matters little which), which remains thus as the type of Cidaris. Moreover Brandt, who was the first writer to subdivide Cidaris, distinctly states that *tribuloides* is the type of Cidaris s. str., and as "first reviser" he undoubtedly had the right to select the type. There is therefore no need of upsetting a number of familiar names and causing considerable confusion by insisting on *papillata* as the type of Cidaris. Indeed, if we are to discuss this question, *imperialis* has a better claim than *papillata* to be the type of Cidaris, for it is undoubtedly the first species Leske names, though he has it confused with *papillata* under the varietal name *major.* In resurrecting Lamarck's name Cidarites, which is clearly a substitute for, and synonym of, Cidaris, Döderlein violates the old principle "once a synonym, always a synonym," and certainly if Dorocidaris A. Ag. is a synonym of Cidaris Leske, as Döderlein says, it cannot be used for a subgenus of Cidarites. It is surprising that so good a zoölogist as Döderlein should have committed two such errors. Since Döderlein's Cidarites equals Cidaris Mortensen and his "Cidaris" is equivalent to Dorocidaris A. Ag., the latter can be added to our list of accepted genera, which will also include several genera of recent Cidaridae adopted by Mortensen, Döderlein, and Agassiz and Clark, as follows: —

Dorocidaris A. Agassiz.	Stereocidaris Pomel.
Chondrocidaris A. Agassiz.	Acanthocidaris Mortensen.

We may also add five genera of fossil Cidaridae, accepted by Pomel, Döderlein, and Duncan, regarding which there can be little question: —

Orthocidaris Cotteau.	Polycidaris Quenstedt.
Temnocidaris Cotteau.	Diplocidaris Desor.
Tetracidaris Cotteau.	

The following genera are fully described and figured by A. Agassiz or by A. Agassiz and Clark, and their validity is not likely to be questioned, with the possible exception of Stephanocidaris, which some zoölogists may not wish to separate from Phyllacanthus. So far as the evidence goes, however, it is fully entitled to recognition.

Stephanocidaris A. Agassiz.	Aporocidaris A. Agassiz and Clark.
Centrocidaris A. Agassiz.	Anomocidaris A. Agassiz and Clark.

There still remain no less than 21 genera and several subgenera of Cidaridae which have been proposed and are entitled to consideration.

To these I have given special attention, but the great majority do not seem to me to be based on sufficiently reliable or tangible characters to warrant their recognition. The following list includes them all, with my opinion as to the proper status of each; those which appear to me to be worthy of use are indicated by black-faced type.

Rhabdocidaris Desor: not distinguishable from Phyllacanthus.
Leiocidaris Desor: " " " "
Eocidaris Desor: not distinguishable from Cidaris, or else from Archaeocidaris, according to what species is considered the type. It is true that the first species mentioned by Desor (*keyserlingi*) does not agree with the diagnosis of the genus, but since Döderlein (**'87**) has definitely selected that species as the genotype, Eocidaris becomes a synonym of Cidaris.
Leptocidaris Quenstedt: very probably not one of the Cidaridae.
Gymnocidaris A. Ag.: not distinguishable from Cidaris.
Prionocidaris A. Ag.: " " " Phyllacanthus.
Schleinitzia Studer: " " " "
Tylocidaris Pomel: apparently a valid genus, though allied to Cidaris.
Typocidaris Pomel: not clearly distinguishable, and too near Cidaris and Dorocidaris.
Pleurocidaris Pomel: not distinguishable from Phyllacanthus.
Plegiocidaris
Paracidaris
Procidaris
Eucidaris } Pomel: hopelessly indistinguishable.
Anaulocidaris Zittel: not distinguishable from Cidaris.
Discocidaris Döderlein: not " " Goniocidaris.
Mikrocidaris
Triadocidaris
Miocidaris } Döderlein: not distinguishable from each other and too near Cidaris and Dorocidaris.
Phalacrocidaris[1] Lambert: ?
Aulacocidaris[1] Lambert: ?
Tretocidaris Mortensen: see below.
Schizocidaris Mortensen: not worthy of separation from Goniocidaris.
Petalocidaris Mortensen: " " " " " "
Histocidaris Mortensen: " " " " " Porocidaris.

[1] I have been unable to see the original descriptions or any figures of these two genera, as the papers in which they are published are not to be found in either Cambridge or Boston. But *Aulacocidaris* (Lambert, 1903; Bull. Soc. Hist. Nat. Savoie, (2) VIII, p. 222) is evidently closely related to *Phyllacanthus* and is probably not distinguishable, while *Phalacrocidaris* (Lambert, 1902; Mem. Soc. Geol. France, Pal. IX, fasc. III, Mem. 24, p. 27) is based on Döderlein's living species of *Stereocidaris* from Japan, but includes a number of fossil forms. As *Stereocidaris* is itself only distinguishable with great difficulty, it is very unlikely that *Phalacrocidaris* is tenable.

The genus Dorocidaris is difficult to separate, on the one hand, from Cidaris, and on the other from Stereocidaris, but is particularly close to the latter, and it is almost impossible to draw a sharp line between them. Moreover, it contains a rather heterogeneous lot of species. One of these, *D. micans* Mortensen, seems to be quite unique, and I think it may well be made the type of a new genus for which I would suggest the name **Calocidaris**. The remaining species fall naturally into three groups, distinguished from each other by their abactinal systems, spines, pedicellariae, and distribution. I see no objection to recognizing these groups as genera, and such a course has some obvious advantages. A typical Dorocidaris such as *papillata* has the abactinal system irregularly angular and often indistinctly defined, and the globiferous pedicellariae have a conspicuous end-tooth on each valve. But other species have the abactinal system circular or pentagonal and sharply defined, and some of the globiferous pedicellariae are often more or less like those of Cidaris. To this group *D. bartletti* A. Ag. belongs, and as Mortensen has made that species the type of a new genus, Tretocidaris, that name must attach itself to this section of Dorocidaris, even though few of the species have the remarkable pedicellariae which Mortensen considers the distinguishing character of the genus. Finally, a group of three small species, characterized by their thickened secondaries, globiferous pedicellariae without end-tooth on the valves, sparsely tubercled abactinal system, and antarctic or subantarctic distribution, may be conveniently designated as **Austrocidaris**. The table on the opposite page gives the genera adopted in the present paper, with their authors, the year in which they were proposed, and the type-species of each. The number of recent species in each, which seem to me valid, is also indicated.

The number of fossil specimens to which specific names have been given is in the vicinity of 200; of these, Döderlein lists 135, but there is reason to believe that many of these represent different ages or individual forms of single species, and it is not unfair to assume that the number of extinct species actually known to science does not exceed the number of species now living. The following key will bring out the obvious if not the most important characters by which the 21 genera here recognized may be distinguished. It is hoped that such a key may be of use to palaeontologists as well as to zoölogists. The dimensions are given in millimeters, and the horizontal diameter of the denuded test (abbreviated for convenience to "h. d."), taken at the ambitus, is used as the unit for determining the relative proportions of the various

Genus.	Author.	Year.	Type-species.	Number of Recent Species.
Cidaris . . .	Leske. . . .	1778	tribuloides Lamarck	3
Phyllacanthus .	Brandt . . .	1835	imperialis Lamarck	5
Goniocidaris .	L. Agassiz et Desor . . .	1846	geranioides Lamarck	7
Diplocidaris. .	Desor. . . .	1854	gigantea Agassiz	0
Porocidaris . .	Desor. . . .	1854	veronensis Desor, but of recent species, purpurata Wyv. Thomson	6
Polycidaris . .	Quenstedt . .	1858	multiceps Quenstedt	0
Orthocidaris .	Cotteau . . .	1862	inermis A. Gras	0
Temnocidaris .	Cotteau . . .	1862	magnifica Cotteau	0
Stephanocidaris	A. Agassiz . .	1863	bispinosa Lamarck.	3
Chondrocidaris	A. Agassiz . .	1863	gigantea A. Agassiz	1
Dorocidaris . .	A. Agassiz . .	1869	abyssicola A. Agassiz . . .	5
Tetracidaris .	Cotteau . . .	1872	reynesi Cotteau	0
Tylocidaris . .	Pomel . . .	1883	gibberula L. Agassiz et Desor.	0
Stereocidaris .	Pomel . . .	1883	cretosa Mantell, but of recent species, grandis Döderlein .	9
Tretocidaris. .	Mortensen . .	1903	bartletti A. Agassiz	9
Acanthocidaris	Mortensen . .	1903	curvatispinis Bell	3
Centrocidaris .	A. Agassiz . .	1904	doederleini A. Agassiz . . .	1
Anomocidaris .	A. Agassiz and Clark . . .	1907	japonica Döderlein.	1
Aporocidaris .	A. Agassiz and Clark . . .	1907	milleri A. Agassiz	3
Calocidaris . .	gen. nov. . .	1907	micans Mortensen	1
Austrocidaris .	gen. nov. . .	1907	canaliculata A. Agassiz . . .	3

21 genera and 60 recent species.

parts. The other abbreviations used are self-explanatory. The "vertical diameter" means the vertical distance from the *margin* of the abactinal system, at the end of an ambulacrum, to the lowest part (usually several millimeters distant from the edge of the actinostome) of the same ambulacrum, measured with a pair of dividers. When the measurement from the *centre* of the abactinal system is normally very different from this, special reference is made to the fact. In all cases maximum measurements are used for comparison; thus, when it is said that the "abactinal system equals .40 h. d.," what is meant is that the *greatest* diameter of the abactinal system (it is not always circular) equals .40 of the greatest diameter of the test. "Primary spines about equal to h. d." means that the *longest* primary is about equal to the greatest diameter of its own test. The relative position of the pores of a pair is indicated as "horizontal" or "oblique," according to whether a line drawn outward from the tubercle on the margin of the median ambulacral area, at right angles to that margin, passes above both pores or

through the outer pore of the pair. Unless otherwise noted, the colors given are those of dried Museum specimens.

In using this, and all other keys given, it should be constantly borne in mind that the younger the individual, the less will it show generic and specific characters; in proportions, number of coronal plates, and of secondary and miliary spines, arrangement of the abactinal system, form of the primary spines, and color, the young are often quite different from the adults. They can only be identified with certainty on comparison with other specimens, old, young, and intermediate, and usually, for very young specimens, it is necessary to know the place and means of collection. On the other hand, unusually large specimens often have the abactinal system and actinostome relatively smaller than in specimens of more moderate size. Variations of five per cent or more, on either side of any mean given, may therefore be expected. The keys are all based on supposedly normal, mature specimens, the age being estimated by the presence and size of the genital openings, the appearance of the primary spines and abactinal system, and to some extent by the size. Although the radial plates of the abactinal system are not connected with any sort of light-detecting or visual organs, they have been so generally called "ocular" (*ocellar* in German and *ocellaires* in French) plates that the name is here retained, as preferable to the alternative term "radial," which Duncan uses, but which is not really quite so distinctive.

Key to the Genera.

Genera marked with an * have no living representatives.

Pores horizontal or nearly so, distant (space between the two of a pair evidently exceeding diameter of a pore); surface of interval flat, or with a groove connecting pores, never elevated. (Individuals in which this feature is obscure are characterized by stout or more or less thorny spines, 1.5–2 5 h. d. [if less than 1.5 h. d., coronal plates very few, 5 or 6], and unsunken and, even actinally, quite distinct areolae.) Recent species exclusively Indo-Pacific.

With pores in 4 more or less regular vertical series in each poriferous zone.

With 4 vertical series of coronal plates in each interradius from actinostome to ambitus . . . . *Tetracidaris*

With only 2 series of coronal plates in each interradius . . . . *Diplocidaris*

With pores in only 2 vertical series in each poriferous zone.

Ambulacral and interambulacral plates with more or less numerous, nearly circular pits, irregularly scattered . . . . *Temnocidaris*

Ambulacral and interambulacral plates without such pits.

Abactinal system of numerous thin plates, with very large anal system around which ocular and genital plates form a single narrow ring; genitals, except madrepore, much wider than high, often twice as wide; oculars nearly as high; collar of primaries spotted with white; lowest actinal primaries with very wide collar and a short thick cap of outer layer of spine, flattened, curved, and somewhat serrate at tip, when fully developed . . . *Stephanocidaris*

Abactinal system not as above; collar of primaries not white-spotted; actinal primaries not provided with a distinct cap.

Median interambulacral area less than .30 of interambulacrum *Phyllacanthus*

Median interambulacral area more than .30 of interambulacrum, densely covered with minute tubercles . . . . . . *Chondrocidaris*

Pores nearer together, usually more or less oblique, often separated by an elevation and never yoked together by a groove.

All primary tubercles large, smooth, and imperforate . . . . **Tylocidaris*

Primary tubercles, at least at ambitus, perforate.

Ambulacra more than half as wide as interambulacra . . . . *Centrocidaris*

Ambulacra not half so wide as interambulacra, usually much less.

Coronal plates with areolae so small their diameter is less than one-quarter horizontal length of plate and only about one-half vertical height . . . . **Orthocidaris*

Coronal plates with areolae which occupy a large proportion of plate.

Ambulacra broad, .35-.45 of interambulacra, with median area correspondingly wide, sometimes sunken and more or less bare; median space of interambulacra, especially along vertical, and inner portion of horizontal sutures, sunken deeper than areolae, especially at angles, and more or less bare; in some species, however, miliary tubercles cover so much of inner half of each coronal plate that parts of vertical suture are concealed and only short, bare, horizontal furrows are visible, and even these may be only faintly indicated. Coronal plates numerous in proportion to h. d., 6–11. Primaries always rough and more or less thorny or prickly, often flaring at tip . . *Goniocidaris*

Ambulacra less than .35 of interambulacra, or, if more than that, primaries not thorny.

Coronal plates numerous and narrow, 9–15, with areolae merging into each other throughout the whole series . . **Polycidaris*

Coronal plates rarely more than 9, areolae at ambitus and abactinally never merged together.

Primary spines long, 2–3 h. d., not at all thorny or prickly, broad and somewhat depressed at base, tapering much but gradually, often slightly curved, and with a conspicuous light-colored or spotted collar, one-fifth or more of the length *Acanthocidaris*

Primary spines very diverse, but never as above.

Only tridentate or, more rarely, bidentate, pedicellariae present, but these abundant and often very large (2–6 mm. high) . . . . *Porocidaris*

Globiferous pedicellariae present, but often only small ones.

Abactinal system very large (.60–.70 h. d.); ambulacral plates few, generally less than 30; poriferous zones not at all sunken; secondary and miliary spines alike, cylindrical and more or less club-shaped; no tridentate pedicellariae present . . . . . . *Aporocidaris*

Abactinal system less than .60 h. d.; ambulacral plates more than 40 (except, of course, in young individuals).

Abactinal surface conspicuously bare, with no primary spines or well-developed tubercles or areolae much above ambitus; no tridentate pedicellariae present . . . . *Anomocidaris*

Abactinal surface not so conspicuously bare; at least two primary spines well above ambitus in each interradius.

Areolae little or not at all sunken; actinostome generally larger than abactinal system, which is usually .40–.45 h. d.; median ambulacral area with only a single marginal series of tubercles, though there are usually other smaller, scattered tubercles between, and these may form 1–5 vertical series. Primaries .65–1.60 h. d. but commonly about equal to h. d., rather stout, usually blunt; secondaries broad, flat, and truncate . . . . *Cidaris*

Areolae more or less deeply sunken; actinostome usually smaller than abactinal system; median ambulacral area usually with a double marginal series of tubercles, inner much smaller. Primaries 1–3 h. d.; secondaries diverse.

Small (25–40 mm. h. d.); abactinal system with few, generally less than 200, tubercles; secondaries, especially ambulacral, rounded, thickened, and more or less club-shaped; no tridentate pedicellariae; large globiferous pedicellariae with no end-tooth on the valves. Subantarctic, north to about 35° S. . . . . *Austrocidaris*

Larger (30–70 mm); abactinal system with more numerous tubercles; secondaries flat and thin, and usually narrow. Tridentate pedicellariae usually present and large globiferous, often with an end-tooth on the valves. Northern hemisphere, seldom south of the equator.

Abactinal system sharply defined, more or less distinctly circular or pentagonal in outline; ocular plates with outer margin convex or straight, little notched by ambulacra. Some or all of large globiferous pedicellariae, if not like small ones, have curved valves, large terminal opening, and no end-tooth, as in Cidaris . . *Tretocidaris*

Abactinal system not very sharply defined, rather irregular in outline, with re-entering angles, between ocular and genital plates; oculars with more or less concave outer margin or deeply notched by ambulacra. Large globiferous pedicellariae never as in Cidaris.

Abactinal system thick and solid, more or less elevated; genital and ocular plates with more or less convex surfaces, thickly and uniformly covered with tubercles of approximately equal size; ambulacral secondaries usually larger than those on genital, ocular, and uppermost coronal plates and often conspicuously contrasted with them. Coronal plates few, 4–7, rarely 8 or 9; uppermost 1 or 2 or even 3 without primary spines. Primaries never smooth, but provided with longitudinal rows of granules, or with ridges, 1 or more of which may be elevated to form conspicuous, though delicate, buttress-like "wings" along basal half of spine; if these buttress-like "wings" are not present, terminal portion of spine often more or less fluted and flaring. Globiferous pedicellariae, both large and small, commonly lack conspicuous end-tooth . . *Stereocidaris*

Abactinal system flat, usually not uniformly covered with tubercles, some of which are also larger than others; ambulacral secondaries not noticeably contrasted with others abactinally. Coronal plates 6–8, rarely 9, all (except usually uppermost 1, or rarely 2) with primary spines. Primaries sometimes perfectly smooth, never with "wings," and seldom with flaring tip. Globiferous pedicellariae, both large and small, commonly with conspicuous end-tooth.

Median ambulacral area .55 of ambulacrum in width; primaries shining as though polished, white more or less shaded with greenish or pink, or both . . . . . *Calocidaris*

Median ambulacral area less than .50 of ambulacrum; primaries never shining as though polished . . . . *Dorocidaris*

The above key gives little clue to the relationships of the genera with each other, and a natural arrangement must necessarily be largely a matter of speculation. There can be little question that Cidaris is

nearest to the ancestral form and the centre from which the different genera have come. Whether Tylocidaris represents a more primitive type, because of its imperforate tubercles, is an open question. The other genera fall rather naturally into three groups, which correspond to the three "sous-tribus" of Pomel, but the lines between these groups are not clear enough to warrant any recognition of subfamilies. The following table indicates these three groups, and in the succeeding pages the genera will be taken up in the order here given, which indicates roughly their possible relationships.

	Tylocidaris.	
	Cidaris.	
Phyllacanthus.	Goniocidaris.	Dorocidaris.
Chondrocidaris.	Polycidaris.	Tretocidaris.
Diplocidaris.	Orthocidaris.	Calocidaris.
Tetracidaris.		Austrocidaris.
Stephanocidaris.		Centrocidaris.
Temnocidaris.		Aporocidaris.
		Stereocidaris.
		Anomocidaris.
		Acanthocidaris.
		Porocidaris.

Diagnoses of the Genera, and the Recent Species.

In view of the large number of recent Cidaridae described since the publication of A. Agassiz's "Challenger" Echini, a complete revision of the family will not be without value, so, to the extended diagnoses of the genera here accepted, artificial keys to the recent species contained in each are added, with a few remarks concerning each one, and a reference to a good figure when one has been published. Three apparently new species, represented in the Museum of Comparative Zoölogy by several specimens each, are also described and figured. No attempt at a synonymy is made, since the "Revision of the Echini" gives all that is needed in that line for the species long enough known to have been burdened with many names. References to published figures are given for every species which has ever been figured, and photographs are added of all species which have never been figured hitherto, except only *Dorocidaris nuda,* of which no specimen has been available.

TYLOCIDARIS.

Tylocidaris Pomel, 1883, Class. Meth. Gen. Ech., p. 109.

Plate 1054, figs. 1-7, Pal. Franç. Terr. Crét., 7, Cotteau, 1862.

Test small or of moderate size, much as in Dorocidaris; coronal plates 5-8; areolae distinctly sunken, sometimes large, and tending to merge together vertically; primary tubercles large, smooth, and imperforate; median interambulacral and ambulacral areas and poriferous zones as in Cidaris or Dorocidaris; pores large, close together, slightly oblique. Abactinal system of moderate size, about .45-.50 h. d. Actinostome somewhat smaller than abactinal system. Primary spines very stout, club- or acorn-shaped. Secondaries and pedicellariae ?

It is difficult to know how much weight can wisely be laid on the absence of perforations in the tubercles, but it is a character never shown in perfect tubercles of living Cidaridae. On the whole, the combination of imperforate tubercles with the curious short, stout spines makes the genus easy to recognize. Döderlein (**'87**) lists four species, all from the Cretaceous of Europe.

CIDARIS.

Cidaris Leske, 1778. Add. Nat. Disp. Ech., p. 17.

Test moderately high; vertical diameter usually about .60 h. d. (ranges from .50-.75); thick and solid (in *metularia*, thickness of an ambulacral plate at ambitus is about .55 of its horizontal length); coronal plates 6-9 (sometimes 10, very rarely 11); areolae not sunken but tending to merge together actinally; median interambulacral area little or not at all sunken, more or less uniformly tuberculated; sutural lines often not visible at all; ambulacra .20-.35 of interambulacra in width; poriferous zones little sunken; median ambulacral area with a single conspicuous marginal series of tubercles and 1-3 (rarely none, or in large specimens 4 or 5) irregular vertical series of much smaller ones between; sutural lines more or less obscured and not conspicuously sunken; pores oblique, with distance between two of same pair about equal to diameter of a pore and with surface of interval more or less elevated. Abactinal system .30-.50 h. d. Actinostome .40-.55 h. d., usually larger than abactinal system, sometimes half as large again. Primary spines about equal to h. d. (range from .65-1.60 h. d.), stout, cylindrical or terete, usually blunt, slightly rough but not thorny, covered with longitudinal series of granules which are usually low and rounded but may be conspicuous and sharp; actinal primaries not peculiar, little or not at all flattened; ends rounded and generally fluted. Secondary spines flat, truncate, rather broad and not tapering towards tip, which may indeed be widened. Pedicellariae of 3 kinds present as a rule, but tridentate may be wanting, or rarely large globiferous ones fail; latter have curved valves, large terminal opening, and no end-tooth.

This genus is one of the most easily recognized of the family, although some of the individuals with long spines approach quite nearly in appearance to *Tretoci-*

daris affinis. Indeed it is possible that some of the specimens of *C. tribuloides* with long, tapering spines, which have been collected in the West Indies, are really hybrids between that species and *affinis*, but there is no proof that this is the case. There are only 3 valid recent species of Cidaris, and they are quite sharply distinct from each other. The form which Döderlein (**'87**) described under the name *galapagensis* is not constantly distinct from *thouarsii* and must be referred to that species. All of the living species are littoral forms, and rarely occur at a greater depth than 50 fths., but are found along nearly all tropical and subtropical coasts. Numerous fossil species from Tertiary, Cretaceous, Jurassic, Triassic, and even Permian strata have been named. The following key to the recent species is based on the examination of 845 specimens representing all three.

Key to the Species.

Small, h. d. rarely exceeding 30 mm.; median areas .45–.60 of ambulacral width, usually bare and often sunken; abactinal system .45–.50 h. d.; genital plates always clearly in contact with each other; coronal plates 5 or 6, rarely 7 . . . . *metularia*

Medium to large, h. d. 30–70 mm.; median areas seldom more than .40 of ambulacral width, always provided with miliary tubercles; abactinal system usually less than .45 h. d.; some or all of genital plates separated in mature specimens; coronal plates 7–10, rarely 11.

- Median interambulacral area more than .10 h d.; abactinal system usually over .40 h. d.; small spines olive, fawn-color, or red-brown, with tips usually darker . . . . *tribuloides*
- Median interambulacral area less than .10 h. d.; abactinal system usually less than .40 h. d.; small spines dark red-brown, purple, or nearly black, with tips not noticeably darker . . . . . *thouarsii*

Cidaris metularia.

Cidarites metularia Lamarck, 1816, Anim. s. Vert., **3**, p. 56.
Cidaris metularia Blainville, 1830, Zoöphytes: Dict. Sci. Nat., **9**, p. 212.

Plate 1g, fig. 1, Rev. Ech., A. Agassiz, 1873.

Although having a far more extensive range than either of the others, this species shows much less diversity in the length and form of the primary spines; they are generally about .80 h. d. and are rarely if ever 1.20 h. d. The stalks of the large globiferous pedicellariae have a well-developed "limb." The colors are generally brighter than in the larger species, and the cross-banding of the primaries is usually very distinct; some Hawaiian specimens are very red, more or less marked with yellowish or reddish white. The geographical range is from Cape of Good Hope, northward on the east coast of Africa into the Red Sea (including Madagascar, Mauritius, Bourbon, and the Seychelles), thence eastward along the

southern coast of Asia with the adjoining islands, through the East Indian archipelego and out into the Pacific, as far as the Solomon, Fiji, and Hawaiian Islands. Curiously enough, *metularia* does not seem to reach either Japan (except the Liukiu Islands) or Australia. The only difference that can be detected between Mauritian and Hawaiian specimens is that, in the latter, the median ambulacral area is somewhat broader and flatter, but the difference is very slight and inconstant.

Cidaris tribuloides.

Cidarites tribuloides Lamarck, 1816, Anim. s. Vert., **3**, p. 56.
Cidaris tribuloides Agassiz, 1835, Prodrome, p. 188.

Plate 1d, Plate 2, figs. 1-3, Rev. Ech., A. Agassiz, 1872.

Little need be said further in regard to this well-known species, save that the primary spines are frequently cross-banded, especially in young specimens, and in old specimens are almost always more or less encrusted with colonies of Bryozoa, and similar foreign material. The relative length and thickness of the primaries differ to a remarkable degree in specimens from different localities. The general appearance of specimens from the Cape Verde Islands is thus strikingly different from that of the ordinary West Indian form. On the other hand, many of the specimens dredged in the West Indies, by the "Blake," have the primaries so long and slender that there is a noticeable superficial resemblance to *Tretocidaris affinis*. Connecting forms between the extremes are, however, common. The stalks of the large globiferous pedicellariae have no "limb." The geographical range is confined to the Atlantic Ocean, from the Bermudas and Azores on the north to Brazil, the Cape Verde Islands, and Cape Palmas on the south. In the Museum are several old tests without spines, which are almost certainly this species, labelled "Mer Rouge," but a mistake in labels is always possible, and these have doubtless been mixed at some time with West Indian specimens. There is also a very small (5 mm. h. d.) but perfect specimen from "51° 26′ S. and 68° 5′ W., 57fths.," collected by the "Hassler." If there has been no mistake, this would indicate a remarkable southern range. Small specimens from Ascension Island, Atlantic Ocean, in the collection of the National Museum, like those collected by the "Challenger" at Bahia, and Fernando Noronha, Brazil, have verticillate swellings on the primaries, but are not otherwise peculiar.

Cidaris thouarsii.

Cidaris thouarsii Agassiz and Desor, 1846, Cat. Rais. Ann. Sci. Nat. (3) **6**, p. 326.

Plate 10, Jap. Seeigel, Döderlein, 1887.

This is the well-known substitute for *tribuloides* on the west coast of America. It is easily distinguished from that species by the color and other characters mentioned above. Its range is comparatively limited, however, as it is not known from south of the equator (save in the Galapagos) nor from north of the Gulf of Cali-

fornia. After a careful comparison of numerous excellent specimens from Mexico, Panama, and the Galapagos, it is clear that there is no constant character by which *C. galapagensis* Döderlein ('87) can be distinguished from *thouarsii*. Specimens from the Galapagos usually have the short and very stout spines figured by Döderlein, and apparently do not have tridentate pedicellariae, but some Galapagös specimens have long, slender, tapering spines, while some from the coast of Mexico have spines like those of most Galapagos specimens; and individuals from Panama occasionally lack the tridentate pedicellariae. Döderlein's present opinion (1906) seems to be that *galapagensis* should be regarded as a variety of *thouarsii*.

PHYLLACANTHUS.

Phyllacanthus Brandt, 1835, Prodrome, p. 267.

Test much as in Cidaris but thinner; thickness of an ambulacral plate only .30–.40 of its horizontal length; coronal plates vary greatly in different species, ranging from 5 to 11; areolae not at all sunken and usually quite distinct even near actinostome; median interambulacral area not deeply sunken, though it may be bare and sutural lines distinct; ambulacra .20–.40 of interambulacra in width; poriferous zones little sunken; median ambulacral area generally with a double series of marginal tubercles (inner much smaller than outer) and 1–4 additional, more or less regular, vertical series between; but when ambulacra are very narrow, median area may be as in Cidaris, and when very broad, median area may be bare and without additional tubercles; pores nearly or quite horizontal; distance between two usually much greater than diameter of pore; surface of interval flat or horizontally grooved, so that pores are connected by a furrow. Abactinal system much as in Cidaris. Actinostome varies greatly in different species. Primary spines exceedingly variable, usually 1.5–3 h. d. and quite stout; actinal primaries either as in Cidaris or somewhat flattened, thick and truncated at tip, slightly curved and somewhat serrate. Secondary spines flat, but length and breadth very variable. Large globiferous pedicellariae variable in form and often entirely lacking, but tridentate and small globiferous pedicellariae are generally present.

Large specimens of this genus are easily recognized, but small ones are often puzzling. In very young specimens the pores are arranged much as in Cidaris, and this condition has not wholly disappeared in specimens 20 mm. in diameter; in *thomasii* even the largest specimens do not have the interval between the pores perfectly flat. On the whole the genus is difficult to characterize properly and the recent species are not well defined. But the combination of characters mentioned in the key to genera is unlike that of any other cidaroid, and with proper care a specimen of Phyllacanthus over 30 mm. h. d. should be recognized without great difficulty. No other genus, however, shows so great diversity in the length and form of the spines, and, as might be supposed, the pedicellariae are also very variable. There seem to be only five valid species in this genus, but it must be confessed that the confusion of *baculosa* with *annulifera*, and the latter with *Stephanocidaris bispinosa*, has led to a most unfortunate situation, and there can be no doubt that a careful revision of the genus based upon abundant material from the

Red Sea, Mauritius, the East Indies, and Australia is sadly needed. In the light of such material I believe that additional species will be recognized, and it is quite possible that the genus will need to be divided. For the present, however, I see no better course than to let the genus stand as it is. It seems to be generally agreed that Studer's **('80)** *Schleinitzia crenularis* is a Phyllacanthus, probably *annulifera;* while the observations of Döderlein **('87** and **: 03)** and de Meijere **(: 04)** show that *Ph. dubia* Brandt **('35)** and *parcispina* Woods **('80)** are apparently synonyms of *imperialis*. The species designated *australis* by Ramsey **('85)** is apparently *baculosa* and *Rhabdocidaris recens* Troschel is clearly *annulifera.* All of the recent species are littoral and are confined to the Indo-Pacific region, but many extinct species have been described from Tertiary, Cretaceous, and Jurassic strata of Europe and America. The following key to the living species is based on the examination of only 118 specimens, but each of the five species is represented by at least four examples.

Key to the Species.

Ambulacra very broad, .40 interambulacra or more; median area broad, sunken and bare; median interambulacral area also sunken and bare; primaries seldom exceed h. d., provided with several whorls of vertical plate-like projections or flat, blunt thorns . . . . *verticillata*

Ambulacra less than .40 interambulacra; median ambulacral and interambulacral areas not conspicuously sunken and bare.

- Collar of primary spines without spots or longitudinal lines of deep red or purple.
  - Coronal plates 5–6 (rarely 7); abactinal system small (.30–.40 h. d.); actinostome large (.50–.55 h. d.) . . . . *imperialis*
  - Coronal plates 6–9 (rarely 10); abactinal system nearly equals or often exceeds actinostome.
    - Primary spines stout 1.5–2.5 h. d., terete, slightly swollen above collar, smooth, or with granules arranged in longitudinal series, becoming ridges near tip; no conspicuous thorns or projections . . . . *thomasii*
    - Primary spines not as above, sometimes flattened at base, usually with conspicuous thorns; collar smooth, reddish or purplish, unspotted . . . . *annulifera*
- Collar of primary spines with noticeable spots of purple or deep red, arranged in longitudinal rows and sometimes merged into lines . . *baculosa*

Phyllacanthus verticillata.

Cidarites verticillata Lamarck, 1816, Anim. s. Vert., **3**, p. 56.
Phyllacanthus verticillata A. Agassiz, 1872, Rev. Ech., pt. **2**, p. 151.

Plate 1f, fig. 3, Rev. Ech., A. Agassiz, 1873.

This well-known and unmistakable species reaches a diameter of 35–40 mm. The general coloration is dark brown and green, with the shades lighter in young

individuals. It ranges throughout the East Indian region, north to Anima Oshima in the Liu-kiu Islands and southward along the east coast of Australia; it has been reported from as far west as Mauritius and Zanzibar, and as far east as the Fiji, Samoan, and Hawaiian Islands. Its occurrence in the latter group seems doubtful, as it was not represented in the very extensive collections made by the "Albatross" in 1903. Although ordinarily a littoral form, a specimen from a depth of 547 fths. is reported by de Meijere (**:04**).

Phyllacanthus imperialis.

Cidarites imperialis Lamarck, 1816, Anim. s. Vert., **3**, p. 54.
Phyllacanthus imperialis Brandt, 1835, Prodrome, p. 268.

Plate 1f, figs. 2, 6, 7, Rev. Ech., A. Agassiz, 1873. Plate 58, figs. 3, 4, Semon's gesam. Ech., Döderlein, 1903.

This is another well-known species, dark brown or purple in color, and of large size (up to 75 mm. h. d). Some or all of the primary spines frequently have two or more narrow rings of light color near the distal end. The geographical range of this species is from the Red Sea and Zanzibar to and throughout the East Indies and along the east coast of Australia. I am in doubt as to whether the varieties recognized by Döderlein are really sufficiently constant to be worthy of names.

Phyllacanthus thomasii.

Phyllacanthus Thomasii A. Agassiz and Clark, 1907, Haw. Pac. Ech.: Cid., p. **15**.

Plates 27-30, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

This handsome species reaches as large a size as the preceding, and the long, tapering, stout spines give it a very characteristic appearance. In the largest specimens the small spines and test are dark reddish-brown, but in specimens .30–.40 mm. h. d., the ambulacra and their spines are very pale brown, in sharp contrast to the interambulacra and abactinal system. At all ages the primary spines are salmon-colored, thickly spotted with white, and having a brown collar, but in old specimens they are more or less encrusted with foreign material which conceals the true color, and the collar is much wider and darker than in the young. This species is known only from the vicinity of the Hawaiian Islands.

Phyllacanthus annulifera.

Cidarites annulifera Lamarck, 1816, Anim. s. Vert., **3**, p. 57.
Phyllacanthus annulifera A. Agassiz, 1872, Rev. Ech., pt. **1**, p. 150.

Plate 58, figs. 5-11, Semon's gesam. Ech., Döderlein, 1903.

This species has been so persistently confused, on the one hand with the much rarer *Stephanocidaris bispinosa* (q. v.), and on the other with an East Indian variety of the much commoner *Ph. baculosa*, that the limits of its geographical

range are really unknown. There appears to be a variety of *baculosa* common in the East Indies, in which the primaries are cross-banded as in this species, and this form has been confused with *annulifera.* Now if de Loriol (**'73**) and Mortensen (**:03**) were correct, it would be clear that Lamarck's *annulifera* is this variety of *baculosa,* and in that case the present species should be called *lütkeni,* as de Loriol clearly figures and describes it under that name. Mortensen says he has examined Lamarck's type and it is *baculosa,* but A. Agassiz examined all of Lamarck's types some forty years ago and satisfied himself that the present species is Lamarck's *annulifera.* In a disagreement such as this it is obvious that the earlier investigation is the one least liable to error, for there had been considerably less time for a chance confusion of labels or specimens. Both de Loriol and Mortensen apparently overlook the fact that A. Agassiz examined Lamarck's types in Paris and that there has never been the slightest reason for supposing that he made any mistake in associating Lamarck's name with this species. Until it can be shown that such a mistake was made, the name it has borne so long should be retained for this species. So far as we now know, it is an Australian and East Indian form, and does not occur in the Red Sea or along the African coast. The Museum of Comparative Zoölogy has two fine specimens from the Gulf of Siam, received from the Copenhagen Museum. They were collected by Mortensen, and labelled by him "Stephanocidaris bispinosa." The species is apparently nearly as variable as *baculosa,* both in coloration and in the form of the primary spines; in some cases the secondaries are green and the primaries cross-banded with purple and green, but in other specimens the secondaries are pale brown and the primaries are dull with less distinct markings. The secondaries usually (perhaps always?) have a median longitudinal stripe, darker than the ground color. The primaries are frequently flattened and widened at the base, tapering to the tip and quite thorny, much as in Stephenocidaris, but they are often nearly cylindrical with few thorns. I am not satisfied that the varieties recognized by Döderlein are sufficiently constant to warrant their recognition by name.

Phyllacanthus baculosa.

Cidarites baculosa Lamarck, 1816, Anim. s. Vert., **3**, p. 55.
Phyllacanthus baculosa A. Agassiz, 1872, Rev. Ech., pt. I., p. 150.

Plate 1f, figs. 4, 5, Rev. Ech., A. Agassiz, 1873. Plate 59, figs. 1–5, Semon's gesam. Ech., Döderlein, 1903.

Common, variable, and widely distributed as is this much-discussed and perplexing species, its true characters and the limits of their variability are still little understood. It seems useless in the present state of our knowledge to attempt to recognize varieties, and we can only say that with all the diversity of coloration and of primary spines, the deep red or purple spots on the collar of the primaries is an obvious character almost always present. It is true de Loriol (**'83**) and de Meijere (**:04**) have described specimens with a narrow unspotted collar, but it is

quite possible that these are not really *baculosa.* It is interesting to note that the purple spots on the collar may merge together, not only longitudinally so as to form parallel vertical lines, but also diagonally, so that the collar appears checkered with light-colored, diamond-shaped spots. These spots are occasionally rounded, and then the color shows some resemblance to that of the primaries of Stephanocidaris. Further evidence of the close relationship existing between that genus and *baculosa* is found in the abactinal system of the latter, where some or all of the ocular plates may be broadly in contact with the anal system. The coronal plates are 8–10 or even 11 in the largest specimens (64 mm. h. d.), and the color is brownish-red or purplish, but is quite variable. The geographical range appears to coincide with that of *imperialis.* A remarkably handsome spine of a Phyllacanthus, quite unlike any of *baculosa* which I have seen, in the Museum collection from "Ile Bourbon," inclines me to Mortensen's (**:03**) view that the identity of *baculosa* and *pistillaris* is still open to question. If it is not doubtful, this species ought to be called by the latter name, as it has precedence in Lamarck's work. Döderlein (**:06**), on the strength of Loven's (**'87**) description and figure, adopts the Linnean specific name *cidaris* for this species, quite overlooking Loven's own statement (p. 146) : "Be that as it may, the species name : Cidaris L., left to its fate by the author himself, is to be laid aside as without validity, though of some historical interest." In the collection of the United States National Museum there is a notably fine specimen (No. 14,032) from the Bonin Islands, labelled "*annulifera*"; the secondaries are very long, with a deep brown longitudinal stripe, and the collar of the primaries has some indistinct white spots as well as the characteristic deep purplish-red dots. It is quite possible this is an undescribed species. In the same collection is a large series of specimens from Aden (No. 21,459), which have been labelled by Dr. Mortensen "Cidaris metularia"; the primaries are remarkably short and stout, much as in Cidaris, and as Mortensen did not clean an ambulacrum, it is not strange that he failed to see the very characteristic poriferous zones. But it is hard to understand how he overlooked the conspicuous purple spots on the collar of the primaries.

CHONDROCIDARIS.

Chondrocidaris A. Agassiz, 1863, Bull. M. C. Z., **1**, p. 18.

Test much as in Phyllacanthus, but densely covered with minute tubercles bearing miliary spines and small globiferous pedicellariae; median interambulacral area very broad, generally .35–.40 of interambulacrum, nearly flat; ambulacra narrow, only .20–.25 of interambulacra ; median ambulacral area covered with about eight vertical series of tubercles, of which the marginal ones are slightly larger ; pores horizontal, widely separated, connected by a groove. Abactinal system .35–.40 h. d., with ocular plates entirely excluded from anal system ; genitals broadly in contact. Actinostome about equal to abactinal system. Primary spines stout, nearly cylindrical, sometimes slightly tapering, about equal to, or somewhat exceeding h. d., provided with stout, blunt, thorny projections, and often near the tip with longi-

tudinal lamellae. Secondary spines few, flat, and blunt, confined to scrobicular circles and margins of ambulacra; latter very slender. Large globiferous pedicellariae usually wanting; tridentate infrequent, with slender straight valves; small globiferous abundant, on very short stalks, with prominent end-tooth on valves.

This is a monotypic genus, closely related to the preceding but easily distinguished at a glance by the peculiarly bare appearance of both ambulacra and interambulacra.

Chondrocidaris gigantea.

Chondrocidaris gigantea A. Agassiz, 1863, Bull. M. C. Z., **1**, p. 18.

Plate 1a, Rev. Ech., A. Agassiz, 1873.

This species is of special interest because of its huge size (up to 95 mm. h. d.), its remarkable primary spines, and its very broad median interambulacral areas densely covered with minute miliaries. The color is brown of some shade, the countless miliaries with a distinctly greenish-yellow cast. It is a curious fact that really young specimens of *gigantea* have not yet been taken, none in the collections of either the National Museum or the Museum of Comparative Zoölogy being less than 75 mm. h. d., and de Loriol's (**'83**) specimen, the smallest yet recorded, was more than half that size. Most of the known specimens are from the Hawaiian Islands, but it is also reported from Lifu, Loyalty Islands (Bell, **'99**), and Mauritius (de Loriol, **'83**). The latter is remarkable for having only 5 coronal plates, while Hawaiian specimens have 8–10. The record of this species from the Lepar Islands, given by Sluiter (**'95**), is said by de Meijere (**:04**) to rest only on spines of "*C.* (*Stephanocidaris*) *bispinosa.*"

DIPLOCIDARIS.

Diplocidaris Desor, 1854, Syn. Ech. foss., p. 45.

Plate 1, fig. 5, Syn. Ech. foss., Desor, 1854.

Test much as in Phyllacanthus; coronal plates 7–8; areolae little or not at all sunken, sometimes merging together actinally; median interambulacral area not sunken or bare, but with few, scattered tubercles; ambulacra narrow, less than .25 of interambulacra in width; poriferous zones more or less sunken; median ambulacral area narrow, with usually only a single marginal row of tubercles, the intervening bare space sometimes conspicuous; pores nearly horizontal and widely separated, in vertically very narrow plates, which are so crowded that they have the appearance of having slipped on each other laterally, so that the pores are apparently in 4 vertical series in each zone. Abactinal system small, with large, usually angular, genital and small ocular plates. Actinostome larger than abactinal system. Primary spines very stout, with longitudinal series of low tubercles which tend to merge into ridges near the tip. Secondaries and pedicellariae?

This genus is very different from any living Cidaridae in the arrangement of the pores, but in all other respects it is strikingly like Phyllacanthus, especially some

specimens of *Ph. imperalis*. The crowding of the pores is very similar to what occurs in Asterias and other starfishes, where the ambulacral plates are so crushed together that a straight, single row of pores is forced into such a zigzag arrangement that it has the appearance of two parallel series. There is no reason to consider the arrangement in Diplocidaris as anything other than a highly specialized condition. It seems strange that it is not found in any living species of Cidaridae. Döderlein (**'87**) lists 5 species of this genus, all from the Jurassic strata of Europe.

TETRACIDARIS.

Tetracidaris Cotteau, 1872, Rev. et Mag. Zoöl. (2), **23**, p. 445.

Plate 29, figs. 7–11, Rev. et Mag. Zoöl. (2), 23, Cotteau, 1872.

Test large, circular at ambitus, somewhat depressed; coronal plates very numerous (16 in each complete vertical series), arranged in 4 series in each interradius from actinostome to above ambitus and thence in a double series to the abactinal system; areolae somewhat sunken; median interambulacral areas narrow and with few miliaries; ambulacra narrow, only about .20 of interambulacra in width; poriferous zones little sunken; median ambulacral area nearly bare, with a marginal series of tubercles and a few scattered miliaries; pores nearly horizontal, widely separated, and crowded into a double series in each zone, much as in Diplocidaris. Abactinal system "large." Actinostome? Primary spines rather slender, nearly cylindrical, somewhat ridged. Secondaries and pedicellariae?

In the arrangement of the pores this species is intermediate between Diplocidaris and Phyllacanthus, but it is not in any sense a connecting link between these genera. It may be regarded as a specialized offshoot of the Diplocidaris branch. Duncan (**'89**) thinks it may be related to Astropyga, and there is some reason for thinking it is not genetically connected with the Cidaridae at all. Only one species is known, *reynesi*, from the European Cretaceous strata.

STEPHANOCIDARIS.

Stephanocidaris A. Agassiz, 1863, Bull. M. C. Z., **1**, p. 18.

Test, ambulacra, interambulacra, and relative proportions as in Phyllacanthus, but coronal plates 6–8; abactinal system .40–.45 h. d. and actinostome either larger or smaller; anal system large and made up of numerous plates (in a specimen 42 mm. h. d. there are over 50 anal plates, and in a young specimen 12 mm. h. d. there are 25); all plates of abactinal system relatively thin; genital plates much wider than high, except madrepore, which is much larger than others; ocular plates wide and high, 4-sided, outer side convex, inner usually correspondingly concave; genitals and oculars together form a ring around anal system of

nearly uniform width except where madrepore juts in.[1] Primary spines somewhat flattened near base, conspicuously thorny; collar wide, greenish, reddish or dark with conspicuous white spots; in young specimens these white spots project as granules, but in mature specimens, collar is smooth; actinal primaries slightly curved, with a very wide collar, often more than half their length, and provided with a distinct cap of outer layer of spine; this cap is truncate, thick, and somewhat serrate. Large globiferous pedicellariae are wanting in all available specimens.

Although there can be no doubt of the close relationship between this genus and Phyllacanthus, the discovery of a new species of Stephanocidaris in the Hawaiian Islands, of which numerous specimens are available for study, shows how clearly justified A. Agassiz ('63) was in making *Cidarites bispinosa* Lamarck the type of a separate genus. The characters shown by the primary spines are exhibited in specimens only 12 mm. h. d., and even in these specimens the genital plates are widely separated; it is not, however, until a diameter of over 20 mm. has been reached that the remarkable character of the abactinal system becomes apparent. The three species here recognized are confined to the central and eastern portions of the Indo-Pacific region. The following key is based on the examination of 106 specimens of the first and third species.

[1] It is worth noting that in a young Stephanocidaris 6 mm. in diameter, the ocular plates are all excluded from the periproct, except that of the left posterior ambulacrum, which barely touches an anal plate; in a specimen 7 mm. in diameter, the left posterior ocular is clearly in contact with the anal system and the right posterior ocular barely touches it; in a specimen 12 mm. in diameter, the two posterior, and the left anterior oculars are all clearly in contact with, while the odd anterior ocular barely touches, the periproct; in another specimen of the same size, all the oculars except the right anterior are clearly included; in a specimen 14 mm. in diameter, and in all larger ones, all the oculars are broadly in contact with the anal system. It seems to be true, therefore, of Stephanocidaris that the oculars of the bivium come into contact with the periproct before those of the trivium do and of the latter the right anterior ocular is the last to enter. Examination of a series of young *Cidaris tribuloides* shows that the same course is followed in that species, except that in one specimen the odd anterior ocular was excluded, while the right anterior was no longer so. These facts are strikingly in accord with the condition often found in Tretocidaris and always in Acanthocidaris, where the right anterior ocular is the only one excluded. And I may add that in *Arbacia nigra* and *spatuligera*, in adult specimens of which the posterior oculars, and often the left anterior, are in contact with the anal system, the same course of entrance of the oculars is followed; and while I have found a very few specimens in which the odd anterior ocular is also insert, I have yet to find an Arbacia in which the right anterior ocular is not excluded. The reason for this condition is not clear.

Key to the Species.

Primary spines not red; interambulacral secondaries whitish with a longitudinal green stripe.

Primaries stout, less than 2 h. d.; ambulacral secondaries dark green; abactinal system larger than actinostome . . . . *bispinosa*

Primaries slender, 2–3 h. d.; ambulacral secondaries like those of interambulacra; abactinal system smaller than actinostome . . . . *glandulosa*

Primary spines red (in young, sometimes greenish) with more or less indistinct cross-bands of white; secondary spines reddish or brownish, not longitudinally striped; abactinal system not larger than actinostome . . . . *hawaiiensis*

Stephanocidaris bispinosa.

Cidarites bispinosa Lamarck, 1816, Anim. s. Vert., **3**, p. 57.
Stephanocidaris bispinosa A. Agassiz, 1872, Rev. Ech., pt. 1, p. 160.

Plate 1f, fig, 1, Rev. Ech., A. Agassiz, 1873.

It would be amusing were it not irritating to note how entirely recent writers have ignored Agassiz's (**'73**) description and figure of this beautiful and apparently very rare species. The trouble appears to date from de Loriol's (**'73**) figure, which is certainly not *bispinosa*, but is probably *P. annulifera*, in one of its various color phases; his figure of *lütkeni* is certainly *annulifera*, while his figure of *annulifera* appears to be *baculosa*. Koehler (**'95**) evidently refers to the same form of *baculosa* under the name *annulifera*, while his *Stephanocidaris bispinosa* is probably true *annulifera*. Bedford (**1900**) has apparently identified correctly his specimens of *annulifera*, so far as can be determined from his figures. Döderlein (**:03**) and Mortensen (**:04**) entirely ignore Agassiz's description, or else intimate that the description is inadequate because it fails to apply to their specimens. As a matter of fact, it seems clear that neither of them has seen a specimen of the real *bispinosa*, but since they call the variety of *baculosa* with banded primaries *annulifera*, they are obliged to do something with their specimens of real *annulifera*, and so they suppose them to be *St. bispinosa*, Agassiz's description and figures to the contrary notwithstanding! Their lead is somewhat reluctantly followed by de Meijere (**:04**), who is unwilling to ignore Agassiz's statements; but he, too, records *Ph. annulifera* as *St. bispinosa*. This species reaches a diameter of over 50 mm. Authentic specimens are known only from Australia and Malacca.

Stephanocidaris glandulosa.

Cidaris (*Cidaris*) *glandulosa* de Meijere, 1904, Siboga-Exp. Ech., p. 13.

Plate 1, figs. 5, 6, Siboga-Exp. Ech., de Meijere, 1904.

Among the interesting Echini collected by the "Siboga," in the Dutch East Indies, were 14 small (7–25 mm. h. d.) specimens, taken at depths of 38–51 fths.,

which de Meijere described as *Cidaris glandulosa*. There can be no question of their close relationship to *St. bispinosa*, and it is quite possible, as de Meijere (p. 5) himself suggests, that they are the young of that species. Besides the characters already mentioned in the key, these specimens were remarkable for the number of large globiferous pedicellariae, like those of *P. baculosa*, which they bore.

Stephanocidaris hawaiiensis.

Stephanocidaris hawaiiensis A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 18.

Plates 24 and 25, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

A large series of specimens of this handsome species was collected among the Hawaiian Islands by the "Albatross," at depths of 20–320 fths. It is a typical member of the genus, and is not at all likely to be confused with any other species. The largest specimens are 34–42 mm. h. d. and have primaries 90–105 mm. long.

TEMNOCIDARIS.

Temnocidaris Cotteau, 1863, Pal. Franç. Terr. Crét., **7**, p. 355.

Plates 1085–1087 bis, Pal. Franc. Terr. Crét., 7, Cotteau, 1863.

Test large, much like Phyllacanthus; coronal plates 6–8; areolae very distinctly sunken; median interambulacral area broad, well covered with miliary tubercles, with more or less horizontal, narrow grooves and deep, circular pits; ambulacra narrow, .20–.25 of interambulacra; poriferous zones considerably sunken; median ambulacral area with numerous tubercles, often arranged in horizontal series, and with a few deep, circular pits; pores widely separated, more or less nearly horizontal and connected as in Phyllacanthus. Abactinal system apparently larger than actinostome. Primary spines stout, as in Phyllacanthus. Secondaries and pedicellariae?

If Duncan ('**89**) is correct in his surmise that the pits are of post-mortem origin, Temnocidaris becomes of course a synonym of Phyllacanthus. Until this can be demonstrated, however, the genus is entitled to recognition. The three species which have been named are all from the Cretaceous.

GONIOCIDARIS.

Goniocidaris Agassiz et Desor, 1846. Cat. Rais. Ann. Sci. Nat. (3), **6**, p. 337.

Test moderately high, .50–70 h. d., but not especially thick or solid; coronal plates numerous in proportion to h. d., 6–11; areolae somewhat deeply sunken; median interambulacral areas deeply and distinctly sunken (deeper than areolae, especially at angles), and usually bare along vertical suture, often with short, bare, lateral depressions along inner end of horizontal sutures; in some cases, however, vertical suture nearly concealed and only lateral furrows conspicuous; in still

other cases, even lateral furrows only faintly indicated; ambulacra broad, .35–.45 of interambulacra; poriferous zones more or less sunken; median area much broader than a poriferous zone, usually sunken and often bare along middle; each ambulacral plate bears a single secondary tubercle, a little above inner pore, and in addition 1–8 miliary tubercles, between which more or less space is left bare (amount of bare space varies greatly in different species; in *tubaria*, entire median ambulacral area is sunken and bare save for marginal tubercles, while in *mikado* scarcely any bare spaces are visible; other species clearly connect these two extremes); pores oblique or rarely horizontal; distance between two less than diameter of pore; surface of interval elevated or roughened. Abactinal system variable, ranging from less than .40 to over .50 h. d. Actinostome about equal to abactinal system or smaller. Primary spines very variable, .75–2.00 h. d., always rough, and thorny or prickly; tips of some usually more or less expanded into a large and conspicuous crown, cup, or even plate, which is often only of a little greater diameter than thickest part of spine, but may become as much as .50 h. d.; actinal primaries variable. rough or serrate, usually somewhat flattened; secondaries thick, of moderate length, more or less flattened, rounded at the end. Tridentate pedicellariae wanting, and large, globiferous ones with no end-tooth on the valves.

The typical examples of this genus, such as *tubaria*, are very easily recognized, but it is less easy to place such species as *florigera* and *mikado*. Nevertheless the genus is very generally accepted and seems to be a natural group. Mortensen (:03) has made two new genera (Petalocidaris and Schizocidaris) and a new subgenus (Discocidaris) out of the species here included in Goniocidaris, but none of these rest on anything better than some trifling peculiarity in the large globiferous pedicellariae. Whether we are to find the origin of Goniocidaris in such a form as *Phyllacanthus verticillata* may be open to question, but the median ambulacral and interambulacral areas of that species could easily be transformed into those of *G. tubaria*, while perfectly horizontal pores are found in *G. biserialis*. There can be little question, in any case, that the three southern species are closely related to each other, and the same is true of the Japanese forms, while *florigera* seems to be structurally, as well as geographically, intermediate. The genus is apparently recent and confined to the southern and western Pacific Ocean. The following key is based on the examination of 133 specimens, including all of the species, except *florigera*.

Key to the Species.

Each coronal plate with but few (30–70) secondary and miliary tubercles, median interambulacral area conspicuously bare and often sunken; median ambulacral area commonly without miliary tubercles, except near margin, so that it is often bare and usually much sunken.

Small (20 mm. or less h. d.); coronal plates, 6–8; abactinal system about .50 h. d. and actinostome nearly equal; some primaries taper to a point, while in many specimens, others, abactinal ones, are abruptly and enormously expanded at tip into a plate, diameter of which may be .50 h. d.; primaries usually more or less covered, at least near base, with a coat of woolly, calcareous hairs . . . . *clypeata*

Moderate or large (20–50 mm. h. d.); coronal plates 6–11; abactinal system generally about .40 h. d., and only partially covered with miliary tubercles of various sizes; primaries seldom pointed and with no covering of woolly calcareous hairs.

Abactinal system equal to, or larger than, actinostome; coronal plates with tubercles near vertical suture much smaller than those next to areolae . . . . *tubaria*

Abactinal system smaller than actinostome; coronal plates with tubercles rather large and of nearly uniform size . . . . . *umbraculum*

Each coronal plate with numerous miliary tubercles, so that median interambulacral area is usually covered by them, except on sutures; if bare sunken areas are conspicuous at all, it is only on inner half of horizontal sutures; median ambulacral area with numerous miliary tubercles, tending to cover it, so that it is never wholly sunken and bare.

Large (25–50 mm. h. d.); abactinal system almost uniformly covered with small tubercles; miliary tubercles on ambulacra, in horizontal series with deep furrows between . . . . *geranioides*

Small (15–35 mm. h. d.); abactinal system not uniformly covered with small tubercles; miliary tubercles in median ambulacral area never conspicuous, but often filling up entire space.

Lower edge of ambulacral plates occupied by minute tubercles, leaving distinct bare spaces forming small, rectangular pits, which alternate with each other; primaries white or whitish in contrast with reddish-yellow secondaries . . . . *florigera*

No definite arrangement of tubercles on ambulacra clear, and no distinct bare pits; primaries not "whitish in contrast with" darker secondaries.

Test high, .60–.70 h. d.; abactinal system much less than vertical diameter; primaries more or less covered with calcareous hairs and usually with a conspicuous, flat, horizontal plate just above collar . . . . *mikado*

Test low, .50–.60 h. d.; abactinal system nearly or quite equals vertical diameter; primaries with relatively few, long and stout thorns, but otherwise smooth . . . . *biserialis*

Goniocidaris clypeata.

Goniocidaris clypeata Döderlein, 1885, Arch. Naturg., **51** Jhrg., 1, p. 82.

Plate 6, Plate 4, figs. 8–20, Jap. Seeigel, Döderlein, 1887.

This is one of the interesting species discovered by Döderlein in Japan, and will be easily recognized from his excellent figures and description. The prevailing color is whitish, pinkish, or brown of some shade. The material collected by the "Albatross" shows beyond question that the little cidaroid described by Döderlein (**'87**) as *Porocidaris gracilis* is a small example of this species, in which the spines with enormously expanded tips are wanting. The "Siboga" cidaroid called *C. hirsutispinus* by de Meijere (**:04**) is also evidently a young example of this species; the secondaries of *clypeata* are frequently exactly like de Meijere's figure. Except this "Siboga" specimen, *clypeata* is known only from the vicinity of Japan.

Goniocidaris tubaria.

Cidarites tubaria Lamarck, 1816, Anim. s. Vert , **3**, p. 57.
Goniocidaris tubaria Lütken, 1864, Bid. Kund. Ech., p. 137.

Plate 10, fig. 5. Plate 11.

Of this well-known species, nothing further need be said than that it seems to be perfectly distinct from *geranioides,* although the color (light yellowish, red, or deep brownish-red) is the same as that of many specimens of the latter. The geographical range of this species is Tasmania and northward along the east coast of Australia; a specimen labelled "Goniocidaris geranioides? East India" is in the collection of the M. C. Z.

Goniocidaris umbraculum.

Goniocidaris umbraculum Hutton, 1878, Trans. N. Z. Inst., **11**, p. 306.

Plate 10, figs. 3 and 4.

This is the New Zealand representative of the preceding species, and so far as can be determined from the three specimens at hand, is well entitled to specific rank. The bright green color of the test and the larger number of coronal plates (10, as against 8 in *tubaria* of the same size) are good characters in addition to those given in the key.

Goniocidaris geranioides.

Cidarites geranioides Lamarck, 1816, Anim. s. Vert., **3**, p. 56.
Goniocidaris geranioides Agassiz et Desor, 1846, Cat. Rais. Ann. Sci. Nat. (3), **6**, p. 337.

Plate 1g, figs. 3, 4, Rev. Ech., A. Agassiz, 1873.

Although this species is quite similar to *tubaria* in general appearance, the differences between them seem very constant; in addition to those mentioned above may be added the frequently darker color (nearly black) and the much less thorny spines of *geranioides.* The geographical range appears to be the same.

Goniocidaris florigera.

Goniocidaris florigera A. Agassiz, 1881, Challenger Echini, p. 46.

Plate 1, figs. 7-20, Challenger Ech., A. Agassiz, 1881.

This "Challenger" species from the East Indies shows the same extraordinary variety in its primary spines which is seen in *clypeata,* and it would be surprising if the pedicellariae were not also variable. As I have no greater confidence in the characters furnished by pedicellariae than I have in those which spines afford, I can find no good reason for recognizing the genera and species based on the "Challenger" material, which Mortensen (: **03**) proposes: — *Discocidaris serrata, Schizocidaris assimilis,* and *Petalocidaris florigera.* Certainly if they are to be

accepted, more adequate descriptions are necessary, and the differences between the three species made more tangible. That *C. fimbriata* de Meijere (**:04**) is identical with *florigera* seems to me practically certain.

Goniocidaris mikado.

Discocidaris (*Cidaris*) *mikado* Döderlein, 1885, Arch. Naturg., **51** Jhrg., 1, p. 80.
Goniocidaris mikado Döderlein, 1887, Jap. Seeigel, p. 15.

Plate 7, Jap. Seeigel, Döderlein, 1887.

This is another of the Japanese echinoids, which Döderlein's excellent work has given us. Although undoubtedly nearly related to the preceding species and to *clypeata*, it is perfectly distinct and easily recognized. The minute, often nearly spherical, secondary spines are very characteristic. The color is almost cream-white, with a purplish tint abactinally and on the primaries. Specimens have as yet been taken only in the vicinity of Japan.

Goniocidaris biserialis.

Stephanocidaris biserialis Döderlein, 1885, Arch. Naturg., **51** Jhrg., 1, p. 79.
Goniocidaris biserialis Döderlein, 1887, Jap. Seeigel, p. 10.

Plate 5, Jap. Seeigel, Döderlein, 1887.

This species is quite unlike the preceding in its general appearance, but resembles it in the obliteration of the bare depressed areas on ambulacra and interambulacra which characterize the typical members of the genus. The color of *biserialis* is quite variable, ranging from dull brownish-yellow, with more or less of a green tint, to yellow, olive-green, or brownish-red. It is known only from the vicinity of Japan.

POLYCIDARIS.

Polycidaris Quenstedt, 1858, Der Jura, p. 644.

Plate 79, fig. 69, Der Jura, Quenstedt, 1858.

Test of moderate size, circular at ambitus, flattened; coronal plates numerous (9–15); areolae somewhat deeply sunken, merging together throughout the entire vertical series, even at ambitus; median interambulacral areas more or less bare and depressed; ambulacra narrow, .15–.22 of interambulacra, straight; poriferous zones little sunken; median ambulacral area with only a single marginal series of small tubercles; pores oblique, near together, separated by a slight elevation. Abactinal system? Actinostome? Spines and pedicellariae?

Döderlein (**'87**) appears to think this genus is near Dorocidaris, but to me it is clear that its relationships are with Goniocidaris. Except for the narrow ambulacra and the merged areolae, *P. nonarius* is strikingly like *G. umbraculum*. Döderlein lists 5 species, all from the Jurassic strata of Europe.

ORTHOCIDARIS.

Orthocidaris Cotteau, 1862, Pal. Franç. Terr. Crét., **7**, p. 364.

Plate 1088, Figs. 1-6, Pal. Franç, Terr. Crét., 7, Cotteau, 1862.

Test of moderate size, circular at ambitus, very little flattened, so that it is subspheroidal; coronal plates numerous (14 or 15); areolae very small, scarcely at all sunken, their diameter less than one-fourth the horizontal diameter of plate at ambitus, and little more than one-half its vertical height; median interambulacral area very broad, covered with miliaries and not sunken; ambulacra narrow, .23 of interambulacra, straight; poriferous zones very narrow, not sunken; median ambulacral area with about 4 vertical series of tubercles; pores oblique, separated by a low elevation. Abactinal system very small, about .25 h. d. Actinostome larger than abactinal system, subpentagonal, about .33 h.d. Spines and pedicellariae?

This is certainly a most un-cidaroid appearing sea-urchin, the straight, narrow ambulacra, the numerous small and nearly uniform miliaries, and the remarkably small areolae and primary tubercles are so unlike the Cidaridae, and yet if the areolae were sufficiently enlarged to merge together vertically, the resemblance to *Polycidaris multiceps* would be quite striking. Only one species has been named, *inermis*, from the Cretaceous of Europe.

TRETOCIDARIS.

Tretocidaris Mortensen, 1903, Ingolf-Exp. Ech., p. 16.

Test moderately high but very variable (.45-.85 h. d.); coronal plates, 4-8; areolae little or moderately sunken, tending to merge together actinally; median interambulacral area more or less depressed, bare or covered with small tubercles, sutural lines usually quite distinct; ambulacra .20-.37 of interambulacra in width; poriferous zones more or less deeply sunken; median ambulacral area with a double series of tubercles along margin, inner much smaller; intervening space may be bare, or more or less covered with scattered tubercles; pores as in Cidaris. Abactinal system .40-.55 h. d., sharply defined, circular, or pentagonal; ocular plates with convex or straight outer margin, little or not at all notched by ambulacra; miliary tubercles covering abactinal system more or less variable in size and somewhat irregularly scattered, leaving bare spaces here and there, especially along margins of genital plates. Actinostome, .37-.50 h. d., generally smaller than abactinal system. Primary spines 1-3 h.d., usually more or less cylindrical or terete, rarely with large and conspicuous thorns, but usually covered with longitudinal series of granules, which may be very low so that spine is nearly smooth or only granular, or may project sharply so that spine is prickly, or may be elevated and merged together so that spine is longitudinally ribbed; actinal primaries equally diverse; secondaries flat and not peculiar. Large globiferous pedicellariae sometimes wanting, sometimes as in Cidaris, sometimes with a very small opening and a powerful end-tooth on valves, and sometimes like small ones, which have a rather large opening and usually an end-tooth.

This genus was established by Mortensen for three recent species (*bartletti*, *annulata*, *spinosa*) hitherto placed in Dorocidaris but whose pedicellariae, he

found, were very different from those of *D. papillata*. While the pedicellariae of *bartletti* are much too variable to be used as the basis for a genus, the abactinal system of that species is so noticeably and constantly different from *papillata* that I think the genus Tretocidaris may well be recognized. There are eight other species of Dorocidaris which fall into the same group. It is a much more natural and better differentiated genus than Stereocidaris, which has been quite generally recognized in the last decade. The species of Tretocidaris are widely distributed, occurring in the North Atlantic, the Caribbean and Mediterranean Seas, the Gulf of Panama, northward along the Mexican coast, among the Hawaiian Islands, along the Japanese coast, southward into the East Indies and as far west as Ceylon. I have not attempted to determine whether any extinct species are to be referred to this genus or not. The following key is based on the examination of 938 specimens, representing all of the species recognized except *tiara*.

Key to the Species.

Test very high, .75–.85 h. d.; ambulacra very broad, .33–.37 of interambulacra, with median line bare; primaries with 8 longitudinal ridges (not notched or granular), pale pink at base, olive-green near tip . . *tiara*

Test more flattened, generally less than .70 h.d.; ambulacra generally less than .33 of interambulacra.

- Median ambulacral and interambulacral areas bare along vertical sutural line; coronal plates 6–8.
  - Test moderately flattened or high, .50–.70 h. d.; actinostome moderate, .35–.45 h. d.; median interambulacral area .25 or more of interambulacrum in width, with several series of miliary tubercles on each coronal plate between scrobicular circle and vertical suture; abactinal system fairly well covered with tubercles; primaries 1.25–2.50 h. d.; West Indian.
    - Abactinal system large, .45–.55 h. d.; areolae at least actinally well-sunken; primaries seldom cross-banded, usually terete, with longitudinal series of numerous minute prickles but never thorny . . . . *affinis*
    - Abactinal system small, .40–.45 h. d.; areolae very shallow; primaries prettily cross-banded with reddish (or purplish) and yellowish (or greenish), sometimes cylindrical, often terete, frequently flaring at tip, not uncommonly flattened at base, with longitudinal series of rather coarse teeth and often more or less thorny . *bartletti*
  - Test much flattened, .45–.55 h. d.; actinostome large (.40–.50 h. d.); median interambulacral area .20 of interambulacrum, with only 1 or 2 incomplete series of miliary tubercles on inner end of coronal plates; genital and ocular plates with margins free from miliaries; Eastern Pacific.
    - Primaries reddish, very slender, 1–1.50 h. d.; thickness of spine about 6 or 7% of length; covered with 14–15 longitudinal series of low, rounded granules; collar and secondaries dark, uniform, brownish-red; no tridentate pedicellariae . . . . *panamensis*

Primaries greenish, often cross-banded with darker, stout, about equal h. d.; thickness 8-12 % of length; covered with 12-13 longitudinal series of coarse, sometimes sharp granules; collar light reddish or whitish; secondaries greenish, with a broad longitudinal stripe of brownish- or purplish-red at tip; tridentate pedicellariae common . . . . *dubia*

Median ambulacral and interambulacral areas not at all bare.

Coronal plates 4 or 5, rarely 6 even in large specimens; primaries slightly swollen near base, terete, almost smooth; large globiferous pedicellariae wanting . . . . *calacantha*

Coronal plates 6-8, rarely 5 even in small specimens; primaries not as above.

Areolae very small, those on largest coronal plate only .60-.65 of length of plate; abactinal system .40 h. d. and actinostome .35 h. d. . . . . *perplexa*

Areolae moderate or large, those on largest coronal plate .70-.75 of length of plate; abactinal system about .50 h. d. and actinostome about .45 h.d.

Primary spines somewhat flattened, at least near base, with about 10 longitudinal series of coarse, sharp granules which usually become fused near tip into ridges; in old specimens these ridges may occupy entire length of spine, no separate granules being visible, while in other cases granules may be conspicuous as sharp prickles almost entire length of spine; primaries white or whitish, spotted or banded with brownish-red or purple; collar very narrow . . . . *bracteata*

Primary spines terete, with 12-15 longitudinal series of fine, sharp granules which do not lose their individuality entirely, even near tip of old spines; unicolor, white or pale yellowish; collar of moderate width . . . . *reini*

Tretocidaris tiara.

Dorocidaris tiara Anderson, 1894, Journ. Asiat. Soc. Bengal, **63**, p. 188.

Plate 5, figs. 2, 2a, Ill. Investigator Zoöl. Ech., Alcock and Anderson, 1895.

This is one of the species collected by the "Investigator," the real position of which is somewhat doubtful, although the figures given in "Illustrations . . . Zoölogy . . . Investigator" (1895, pt. 2, plate 5, figs. 2 and 2a) indicate its position in Tretocidaris. The test is extraordinarily high, even though the measurements given by Anderson represent some other method of estimating the height of the test than that which is here used. There are several reasons why *tiara* is not synonymous with *St. indica* Döderlein, as has been suggested, but it is still more incredible that it should be *T. bracteata*, as Mortensen (:**03**, p. 173) asserts, unless Anderson's description and figures are to be entirely ignored. Either Mortensen has not seen a specimen of *bracteata*, or else his supposed specimen of *tiara* is not *tiara* at all. Anderson's figures and description are remarkably clear and complete, and unusually satisfactory, although he

fails to mention the pedicellariae. The test of *tiara* is chestnut-brown, green abactinally, especially towards the anus; the secondaries are olive-green with a darker longitudinal band. The largest specimen was 42 mm. h. d. The only recorded locality for *tiara* is off Colombo, Ceylon, in 142–400 fths.

Tretocidaris affinis.

Cidaris affinis Philippi, 1845, Arch. Naturg., **11** Jhrg., 1, p. 351.

Plate 1, fig. 5, Rev. Ech., A. Agassiz, 1872. Plate 1, fig. 1, Ingolf-Exp. Ech., Mortensen, 1903.

This well-known species has been confused with *Dorocidaris papillata* so long that it may be hard to believe it is really quite different. We are indebted to Mortensen (:**03**) for showing its right to specific rank (although he makes no reference to the abactinal system !), but we cannot follow him in placing it in the genus Cidaris. Mediterranean and West Indian specimens appear to be alike in all particulars ; Mortensen says the tridentate pedicellariae were wanting in his Mediterranean specimens, but those in the collection of the M. C. Z. from Cape Sagras and from the Mediterranean have them normally developed. Mortensen says the spines are 1–1.5 h. d., but our large series of specimens show a much greater range, 1.25–2.40 h. d. The largest specimen is 38 mm. h. d. The color is variable, but the small spines of the test are more or less greenish, tipped with dark red, while the entire abactinal system (or at least the sutural lines) and the bare areas on ambulacra and interambulacra are dark red ; the primaries are dull grayish, more or less pink or white near base, and with a greenish or brownish collar. In West Indian specimens the color is often very light, the secondaries and test being nearly cream-color with the former tipped with reddish. In other West Indian specimens the color is sometimes nearly slate-color, with little trace of reddish. This species ranges throughout the North Atlantic eastward into the Mediterranean, and southwestward to Barbados and the Gulf of Mexico, down to a depth of 500 fths.

Tretocidaris bartletti.

Dorocidaris Bartletti A. Agassiz, 1880, Bull. M. C. Z., **8**, 2, p. 69.
Tretocidaris bartletti Mortensen, 1903, Ingolf-Exp. Ech., p. 16.

Plates 8 and 9. Also Plate 2, figs. 16–27, Blake Ech., A. Agassiz, 1883.

In his original description Agassiz called attention to the resemblance between the primary spines of this species and of Stephanocidaris. Young specimens of *bartletti*, for this reason, show quite a striking resemblance to young specimens of that genus, but a careful examination shows important differences in the primaries as well as in the test. In spite of the very great diversity exhibited in both its spines and its pedicellariae, there can be no question as to the real relationship of this species. Mortensen (:**03**) names two closely allied, supposedly new species, which he found in the British Museum ; one, *annulata*, I am unable to distinguish

from *bartletti*, for no characters are given which do not occur in some specimens of that species; the other, *spinosa*, may prove to be a valid species, but its affinities cannot be determined from the published description. The largest specimen of *bartletti* in the collection of the Museum of Comparative Zoölogy is 49 mm. h. d.; another (Plates 8 and 9), not quite so large (47 mm. h. d), has the longest spines 93 mm., nearly all cylindrical and not at all thorny. The test of these specimens is brown, varying from fawn-color to deep red-brown, or even deep red on the abactinal system. In the National Museum there is a magnificent specimen of *bartletti* 68 mm. in diameter. This species is known only from the West Indies in 88–397 fths.

Tretocidaris panamensis.

Dorocidaris panamensis A. Agassiz, 1898, Bull. M. C. Z., **33**, p. 73.

Plates 1, 2, Pan. Deep Sea Ech., A. Agassiz, 1904.

This handsome species is the Pacific representative of *T. affinis*, but is quite obviously distinct. The tridentate pedicellariae are wanting in all of the thirteen specimens examined, of which the largest is 35 mm. h. d. The geographical range of *panamensis* seems to be limited to the west coast of Central America and around Cocos Island, in 66–112 fthms.

Tretocidaris dubia, sp. nov.

Plate 6, figs. 3 and 4.

Test somewhat flattened; vertical diameter about .52 h. d.; coronal plates 6; areolae distinct and not very deeply sunken; median interambulacral area not sunken, very sparsely covered with tubercles, only 6 or 7 on each coronal plate in addition to the scrobicular circle; ambulacra wide, nearly .40 of interambulacra; poriferous zones broad and little sunken; median ambulacral area with a double series of rather large tubercles on each margin, with space between perfectly bare; pores slightly oblique, rather large. Abactinal system .45–.50 h. d., nearly circular, and clearly defined, elevated at centre, very sparsely covered with small secondary spines; genital plates rather large, higher than wide, with pores near outer edge; ocular plates more or less triangular, one (right anterior) or more excluded from anal system, which is about one-half of abactinal system and has an outer series of 7–10 rather large plates and 9–12 smaller ones at centre; all plates of abactinal system carry a few rather coarse tubercles of nearly uniform size; each genital plate has 14–20 ± such tubercles and each ocular, 8–12 ±. Actinostome slightly smaller than abactinal system, not at all sunken, closely covered with stout plates, 3 or 4 in each interambulacrum and about 8 or 9 pairs in each ambulacrum. Primary spines short, about equal to h. d., nearly cylindrical, seldom tapering, but often truncate or slightly flaring at tip, covered with 12–13 low, longitudinal series of coarse, sometimes sharp granules; actinal primaries much as in Cidaris and usually longitudinally ridged at tip; secondaries long and narrow, flat and slightly widened at tip. Pedicellariae not peculiar; large and small globiferous, as in *panamensis*; tridentate much as in *affinis*. General color of test decidedly greenish, especially abactinally, but anal system reddish-brown; miliary and secondary

spines whitish, longitudinally striated with deep reddish-purple; on secondaries, striations merge to form a broad stripe at tip of spine; primary spines dull grayish, sometimes indistinctly cross-banded with brown; collar flesh-color or whitish. Largest specimen 25 mm. h. d.; vertical diameter, 13 mm.; abactinal system, 12 mm.; actinostome, 11 mm.; longest primary, 25 mm., a trifle more than 2 mm. thick at base.

That this species is closely related to *panamensis* seems clear, but that it is quite distinct is certainly indicated by the available material. None of the specimens of either are in any way intermediate. Both species were taken by the "Albatross" at Station 3378, in 112 fathoms off Galera Point, Cape San Francisco, Ecuador, but only *panamensis* was found near Cocos Island, and only *dubia* at Station 3397, in 85 fathoms off Galera Point. Possibly *dubia* is a more southern species; at any rate, it is known only from the coast of Ecuador.

Tretocidaris calacantha.

Dorocidaris calacantha A. Agassiz and Clark, 1907, Haw Pac. Ech. Cid., p. 11.

Plates 13, 14, 34, 35, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

This very distinct species reaches a size of 43 mm. h. d., with spines 81 mm. long. It is very pale brown with a greenish cast, especially on the abactinal system; the secondaries each have a broad green stripe; the primaries are very faintly banded with brown and at the base are finely spotted with white. This is one of the species found by the "Albatross" at the Hawaiian Islands, where it is not rare in 127–198 fths.

Tretocidaris perplexa, sp. nov.

Plate 6, figs 1 and 2; and Plate 7, figs. 1–4.

Test somewhat flattened; vertical diameter, about .55 h. d.; coronal plates 7 or 8; areolae small, only .60–.65 of horizontal length of plate, distinct and not very deeply sunken; median interambulacral area very fully covered with tubercles, smallest next to vertical suture, which is quite distinct; ambulacra about one-third of interambulacra in width; poriferous zones, broad and little sunken; median ambulacral area with a double series of tubercles on each margin, inner much smaller, and between these, 3–6 irregular series of small tubercles which sometimes, but not always, conceal vertical suture; pores nearly horizontal, large, their horizontal diameter much exceeding vertical. Abactinal system about .40 h. d., nearly circular and clearly defined, flat and quite thickly covered with small secondary spines; genital plates rather large, nearly square or somewhat pentagonal, with pores near outer edge; ocular plates more or less triangular, with apex truncated, when in contact with anal system, either wholly excluded, or some, or all except right anterior one, in contact with a large anal plate; anal system about one-half of abactinal, with an external series of 10–12 large plates and 12–15 smaller ones at centre; except along margins all plates of abactinal system covered with rather coarse tubercles of nearly uniform size; each genital plate has 50–80 ± such tubercles and each ocular 20–35 ±. Actinostome small, only about .35 h. d., not at all

sunken, closely covered with stout plates, 4 in each interambulacrum and about 10 pairs in each ambulacrum. Primary spines short, about equal to h. d., nearly cylindrical, seldom tapering, but often flattened and widened at tip, covered with 14–24 longitudinal series of coarse, sharp granules; actinal primaries much as in Cidaris and nearly smooth; secondaries, long and narrow, but rather thick and often with a deep longitudinal furrow on outer surface at tip, which is thus crescent-shaped in cross-section. Pedicellariae not peculiar; no large globiferous ones were found, but small globiferous and tridentate, like those of *dubia*, are frequent. General color of test decidedly greenish, especially abactinally; miliary spines greenish; secondary spines greenish with a broad longitudinal stripe of deep reddish-purple; primary spines dull grayish with a bright olive-green base and collar. Largest specimen, 50 mm. h. d.; vertical diameter, 27 mm.; abactinal system, 20 mm.; actinostome, 18 mm.; longest spine, 40 mm., 3 mm. thick at base, 5 mm. wide at tip.

In some ways this species is much like *dubia*, but aside from the differences in the tuberculation of the test, the small areolae, abactinal system and actinostome, and the short primaries with olive-green collar and conspicuously flattened tips, are very characteristic of *perplexa*. The resemblance between the two species in the color of the secondary spines is quite noticeable. Two of the five known specimens of this species were collected by the "Albatross" in the Gulf of California on a bottom of coarse sand, in 36–39 fathoms. The other three are said to have been picked up on the shore of Clarion Island, the westernmost of the Revilla Gigedo Islands.

Tretocidaris bracteata.

Dorocidaris bracteata A. Agassiz, 1879, Proc. Amer. Acad., **14**, p. 197.

Plate 10, figs. 1 and 2.

This is apparently the East Indian representative of *bartletti*, though it is a smaller species and obviously quite different. Mortensen (**: 03**), on the supposed characters of the large globiferous pedicellariae, places *bracteata* in Stephanocidaris, but as we have already seen, he probably did not have a specimen of that genus for comparison. Moreover, the pedicellaria which he figures as a "large globiferous" of *bracteata* is exactly like the *small*, globiferous pedicellariae of this species, while the large globiferous pedicellariae of this species are actually like those of Cidaris. However, these large ones are very infrequent and may be wanting, while the small ones are often very large, and it is apparently one of these latter that Mortensen has figured as the characteristic pedicellaria of Stephanocidaris! It seems to me that this serves as an illustration of the danger of relying on the pedicellariae. This species is relatively small, the largest specimen being only 29 mm. h. d. The secondaries are pale purple or rose, with or without yellowish tips, or flesh-colored with a longitudinal rosy stripe; in old specimens those of the ambulacra may be darker than those of the interambulacra, and thus noticeably contrasted with them, and the abactinal system is dark brownish-red; the primaries always show more or less clearly the dark markings, which are usually pur-

plish, but may be reddish or greenish. Originally discovered by the "Challenger" near Amboina, this species has since been taken only by the "Albatross" in Sagami Bay, Japan. Its bathymetric range is 15–114 fms.

Tretocidaris reini.

Cidaris (*Dorocidaris*) *reini* Döderlein, 1887, Jap. Seeigel, p. 7.

Plate 4, figs. 1–7, Jap. Seeigel, Döderlein, 1887. Plate 1, figs. 2, 3, Siboga-Exp. Ech., de Meijere, 1904.

Although this species is closely related to the preceding, the material at hand supports Döderlein's opinion that his Japanese specimens were a new species; curiously enough, however, he makes no reference whatever to *bracteata!* The primary spines of the two species are quite distinct, as already shown; the ocular plates of *reini* are narrower and higher than in *bracteata* and more broadly in contact with the anal system, and the difference in color is very marked; when *reini* is not uniformly yellowish with dull white spines, the uppermost coronal plates, the interambulacral miliary spines, the genital plates and the anal system are deep reddish, while the ocular plates and ambulacra with all their spines are pale yellowish in marked contrast, just the opposite of the coloration in *bracteata;* the primaries of *reini* are apparently not banded or spotted in adults, but if de Meijere's identification of his small East Indian specimens is correct, the young must be very much like those of *bracteata.* In size and in the pedicellariae, the two species agree well; the largest *reini* reported is 34 mm. h. d. Excepting the four young Cidaroids taken by the "Siboga" near the Kei Islands and Timor which de Meijere refers to this species, but which might just as naturally be called *bracteata*, *reini* has not been taken yet anywhere but in Sagami Bay and Kagoshima Gulf, Japan, in 83–158 fths.

DOROCIDARIS.

Dorocidaris A. Agassiz, 1869, Bull. M. C. Z., **1**, p. 254.

Test much as in Tretocidaris, but ranging up to only .70–.75 h. d. Abactinal system very different, its outline not often sharply defined and rather irregular, with re-entering angles between genital and ocular plates; latter more or less pentagonal and deeply notched by ambulacra. Primary spines cylindrical, at least near base, or terete, sometimes smooth, but usually with longitudinal series of granules, or ridges, never "winged" however, and generally not flaring at tip. Globiferous pedicellariae, both large and small, with a conspicuous end-tooth on the valves; tridentate pedicellariae usually present.

Although this genus is quite easily distinguished from the preceding, the line of division between it and Stereocidaris is exceedingly hard to draw, and it is an open question whether there is sufficient ground for keeping them separate. As small genera are more convenient and wieldy, however, we may retain the division recognizing that the line is a very arbitrary one. As here used, Dorocidaris includes five species, which are found only in the Atlantic Ocean and almost entirely

north of the equator. Numerous fossil Cidaridae from Tertiary, Cretaceous, Jurassic, and possibly even Triassic strata are to be referred to either this genus or the preceding. The following key is based on the examination of 536 specimens, representing all of the living species, except *nuda*.

Key to the Species.

Primary spines more or less white and smooth, rarely conspicuously granular, prickly, or ridged, and neither flaring nor conspicuously flattened at tip; median ambulacral area less than .50 of ambulacrum and almost wholly covered with small tubercles . . . . *abyssicola*

Primary spines more or less prickly, granular, or ridged.

Each coronal plate with only a few tubercles on inner half (generally less than 25, not counting scrobicular circle); sutural line of ambulacra usually distinctly visible; each ambulacral plate with 1 or 2, seldom 3, tubercles; primaries more or less cylindrical, often flaring at tip, and never conspicuously flattened there; median interambulacral area less than .25 of interambulacrum in width; sutural line usually quite distinctly sunken and bare.

Whole abactinal surface well covered with light-colored secondary and miliary spines . . . . *papillata*

Whole abactinal surface appearing noticeably bare from small number of secondary and miliary spines present; test light-colored, but all spines reddish-brown or purple . . . . *nuda*

Each coronal plate with numerous (more than 30) tubercles on inner half; sutural line of ambulacra often not visible, each plate with 2–5 tubercles.

Median interambulacral area less than .25 of interambulacrum; sutural line quite distinct; abactinal system with numerous tubercles (genital plate with 110 ±; ocular with 30 ±); primaries often flattened near tip, sometimes greatly expanded into broad flat fans . . . . *blakei*

Median interambulacral area often more than .25 of interambulacrum; sutural line well concealed by tubercles; abactinal system with rather few, large tubercles (genital plate with 55 ±; ocular with 20 ±); primaries terete, covered with sharp granules and never either conspicuously flattened or flaring at tip . . . . *rugosa*

Dorocidaris abyssicola.

Dorocidaris abyssicola A. Agassiz, 1869, Bull. M. C. Z., **1**, p. 253.

Plate 1, figs. 1–4, Rev. Ech., A. Agassiz, 1872.

This species seems to be quite distinct from *papillata*, and while it is occasionally much like *blakei* or *rugosa* in certain features of the test, the primaries commonly distinguish it from either of them at a glance. In addition to the characters given in the key may be mentioned the following: the abactinal system is very large (.48–.55 h. d.), while the actinostome is relatively quite small (.35–.45 h. d. but only .70–.80 of the abactinal system); the test is usually under

.60 h. d. in vertical diameter, and it, as well as the secondaries, is pale brown or yellowish; the abactinal system is sometimes quite red; the uppermost coronal plates do not carry primaries, and even the second ones may lack a well-developed spine; the primaries are usually about 1.25 h. d. and never exceed 2 h. d. The diameter of the test is usually about 25 or 30 mm. but is sometimes 35 or 40, and the largest specimen is 68 mm. h. d. This species ranges from St. Lucia northward to the coast of South Carolina and the region south of Martha's Vineyard at depths of 100–200 fths.

Dorocidaris papillata.

Cidaris papillata Leske, 1778, Add. Nat. Dis. Ech. Klein, p. 61 (*partim*).
Dorocidaris papillata A. Agassiz, 1869, Bull. M. C. Z., **1**, p. 254.

late 1b, Rev. Ech., A. Agassiz, 1872.

Nothing more need be said of this well-known species than that it does not seem to occur in the western part of the Atlantic, but is apparently confined to the northern and eastern parts of that ocean and to the Mediterranean Sea. The bathymetric range is from a few fathoms down to about one thousand. Mortensen's (:**03**, p. 170) assurance that the "Challenger" specimen from St. Paul's Rock is really *papillata* is important in this connection, but I think it possible that the individual may prove to be *rugosa!* In size *papillata* reaches a diameter of 58 mm., while in color it is quite variable, ranging from grayish-white to reddish-yellow, becoming brick-red on the abactinal system, with dull grayish or yellowish primaries.

Dorocidaris nuda.

Dorocidaris nuda Mortensen, 1903, Ingolf-Exp. Ech., p. 171.

This species is apparently distinct from all the other members of the genus, but its real relationships can only be determined when it is more fully described. Possibly it is not so closely allied to *papillata* as I have assumed. The size is not mentioned, but the test is white and the spines purple or reddish-brown. It has been taken only in the Gulf of Guinea and near the Cape Verde Islands, in 53–250 fths.

Dorocidaris blakei.

Dorocidaris Blakei A. Agassiz, 1878, Bull. M. C. Z., **5**, p. 185.

Plate 4, Bull. M. C. Z., 5, 9, A. Agassiz, 1878. Plate 1, Blake Ech., A. Agassiz, 1883.

This is one of the most interesting discoveries of the "Blake," and specimens with fully developed primaries are indeed unique. The color is grayish with more or less of a yellow-brown tinge to the test. The largest specimen is 37 mm. h. d. with spines 76 mm. long. Specimens in which there are none of the conspicuously flattened primaries are easily recognized by the large abactinal system,

.45–.55 h. d., almost uniformly covered with small tubercles; the narrow poriferous zones, about .20 of ambulacra, and the numerous small tubercles on the interambulacra. This species ranges from Havana to Barbados in 197–150 fths.

Dorocidaris rugosa, sp. nov.

Plates 4 and 5. Plate 7, figs. 5–8.

Test rather high, vertical diameter about .60 h. d.; coronal plates 7; areolae deeply sunken and distinct; median interambulacral area very fully covered with tubercles, smallest next to vertical suture, which is quite distinct; ambulacra less than one-third of interambulacra in width; poriferous zones narrow and deeply sunken; median ambulacral area with a double series of marginal tubercles, inner much smaller, and between these some small scattered tubercles tend to conceal vertical suture; pores oblique, small. Abactinal system about .45–50 h. d., irregular in outline, stout and heavy somewhat as in Stereocidaris, covered with rather coarse tubercles; genital plates somewhat pentagonal, with lateral margins concave, and pores not far from centre; ocular plates more or less pentagonal, usually wholly excluded from anal system, but posterior ones sometimes in contact with anal plates, more or less notched on outer edge by ambulacra; anal system not quite one-half of abactinal, with an external series of 10–12 large plates and 12–15 smaller ones at centre; except along margins all plates of abactinal system covered with rather coarse tubercles of nearly uniform size; each genital plate has 50–60 ± such tubercles and each ocular plate 20–30 ±. Actinostome small, about .40 h. d., not at all sunken, closely covered with stout plates, 5 in each interambulacrum and about 10–12 pairs in each ambulacrum. Primary spines long, 2–2.5 h. d., terete, usually swollen just above collar, and thence tapering to tip, covered with 12–16 longitudinal series of conspicuous sharp granules; actinal primaries slightly flattened, a little curved and somewhat serrate; secondaries not peculiar, of moderate length and width, flat, blunt, or truncate at tip. Pedicellariae as in *papillata*. General color of test yellowish or brownish, more or less rose-red or brick-red, abactinally; secondaries and miliaries same as test; primaries whitish or grayish, abactinal ones sometimes bright rose; neck smooth, polished, white, brownish, or pink; collar narrow, pale brownish or rarely lighter than neck. Largest specimen in the Museum of Comparative Zoölogy, 40 mm. h. d.; vertical diameter, 24 mm.; abactinal system, 20 mm.; actinostome, 17 mm.; longest primary, 80 mm., 5 mm. thick near base, somewhat more than 1 mm. thick at tip. In the National Museum is a fine specimen 60 mm. h. d.

This species is clearly the representative of *papillata* in the western Atlantic, but may be readily distinguished from that species by the broader and more completely covered median interambulacral area, the much more fully tubercled median ambulacral area, the more uniformly tubercled abactinal system, and the terete and very prickly primary spines. The distribution of *rugosa* is only imperfectly known; the specimens I have examined are from stations between 32° N. lat. (off Savannah, Ga.) and Barbados and St. Vincent, in 164–337 fathoms. There are 8 specimens in the collection of the U. S. National Museum, several of which have been labelled by Mortensen. One (No. 21,444) is labelled "Stereocidaris ingolfiana," which is a very natural mistake, as small

specimens of the two species are very difficult to distinguish. The others are labelled "Dorocidaris papillata," which is what one would naturally call them, if *rugosa* is not to be recognized as valid.

CALOCIDARIS, gen. nov. (Greek, καλός, beautiful, + *cidaris*).

Test large and rather high; coronal plates 7 or 8; areolae distinct and considerably sunken, the most actinal tending to merge together vertically; median interambulacral area not at all sunken, covered with numerous miliaries and with more or less horizontal grooves or narrow furrows, such as occur in Temnocidaris; ambulacra about .25 of interambulacra in width; poriferous zones scarcely at all sunken; median ambulacral area very wide, about .55 of ambulacrum, with very few tubercles aside from the customary double marginal series; pores oblique, large and close together. Abactinal system not quite .50 h. d., of very irregular outline; ocular plates deeply notched by ambulacra. Actinostome very small, only about .65 of abactinal system. Primary spines 3 h. d., cylindrical, white, smooth, and polished like porcelain, more or less tinged with pink and green; actinal primaries flat and longitudinally fluted, but not notched or serrate. Secondaries flat and tapering, many bluntly pointed. Pedicellariae as in Dorocidaris.

Although in many respects like Dorocidaris, the very broad and nearly bare median ambulacral areas, the remarkable color, and especially the smooth, polished primaries, mark this genus at a glance. The largest primaries are all broken in the specimen in the Musum of Comparative Zoölogy, so that their length is not shown in the figure given. But a specimen in the U. S. National Museum, which is the most beautiful echinoid I have ever seen, is nearly perfect. The primaries are 160 mm. long, rather more than 3 times the diameter of the test, and scarcely taper at all, but are cylindrical throughout their entire length. The genus is monotypic and very few specimens are known. The above description is based on a specimen 61 mm. h. d., from near Barbados, but two other specimens in the U. S. National Museum have been examined.

Calocidaris micans.

Dorocidaris micans Mortensen, 1903, Ingolf-Exp. Ech., p. 23.

Plate 3.

This is easily the handsomest, as well as one of the largest, of the West Indian cidaroids. It reaches a diameter of more than 60 mm. The test is white, and the secondaries nearly so, but the abactinal system and adjoining coronal plates are pale green; the primaries when dry are shining white, with a pink base and occasional faint, irregular marks of the same color; they look as though artificially polished. In alcoholic specimens the spines have a greenish shade and the pink is deeper. The only known specimens of this beautiful species were taken by the "Albatross" off the northwestern coast of Cuba in 205 fths., and by the "Blake" off Barbados in 125 fths.

AUSTROCIDARIS, gen. nov. (Latin *auster*, the south wind, + *cidaris*).

Test flattened, .50–.60 h. d., but otherwise much as in Dorocidaris; abactinal system much more sparsely covered with miliaries; secondaries more or less nearly cylindrical and thickened at tip; primaries generally short, often less than h. d., and usually smooth (in individuals where primaries are long and rough, secondaries are nearly flat, so that resemblance to Dorocidaris is marked). Tridentate pedicellariae wanting and globiferous pedicellariae with no end-tooth on valves; eggs and young carried by female (*mortenseni?*).

Were it not for their geographical isolation it would hardly be worth while to attempt the separation of these three small species from Dorocidaris, but as they have the above given peculiarities in common and are probably more nearly related to each other than to any other forms, it is convenient to keep them apart. They are confined to the southern parts of the Atlantic and Indian oceans, their known range extending from 75° W. to 90° E. longitude and from about 35° to nearly 70° S. latitude. The following key is based on the examination of 70 specimens of *nutrix* and *canaliculata*.

Key to the Species.

Actinal primaries not conspicuously flat, trowel-shaped, and entire.
- Median ambulacral and interambulacral areas bare and more or less deeply sunken; interambulacral area usually with a conspicuously deep vertical furrow; vertical diameter about .55–.60 h. d.; abactinal system and actinostome rather small, .35–.40 h. d., about equal, or former smaller . . . . *canaliculata*
- Median ambulacral and interambulacral areas little bare, and not at all sunken; vertical diameter about .45–.55 h. d.; abactinal system and actinostome large, about .50 h. d., about equal or former larger . . *nutrix*

Actinal primaries conspicuously flat, trowel-shaped, and entire; primaries long . . . . *mortenseni*

Austrocidaris canaliculata.

Temnocidaris canaliculata A. Agassiz, 1863, Bull. M. C. Z., **1**, p. 18.

Plate 1, g, fig. 2, Rev. Ech., A. Agassiz, 1873. Plate 2, figs. 1–3, Challenger Ech., A. Agassiz, 1881.

Some of the differences between this species and the next have already been set forth by Mortensen (:**03**), but he has entirely ignored the more important differences in the test and abactinal system. Moreover he has himself been led astray by the remarkable diversity which this species exhibits in its color, spines, and pedicellariae, and has described as a new species of Stereocidaris, which he calls *lorioli*, the long-spined form of *canaliculata*, which the "Challenger" collected off the mouth of the River Plate (Station 320). The Museum of Comparative Zoölogy contains one of the "Challenger" specimens from St. 320, and also a large

series of specimens from Patagonia. The latter so completely yet gradually connect the individuals having primaries 2.5 h. d. with those from the Falkland Islands in which the primaries are only .65 h. d., that their identity cannot be doubted. Had Mortensen carefully examined an interambulacrum, he probably would not have been misled. Although usually about 25–30 mm. h. d., there are specimens of *canaliculata* at hand 36 and 39 mm.; the primaries range from 16 to 63 mm. The color varies from very pale yellowish (with pink necks on the primaries) to very dark brown. This species is apparently confined to the eastern and southern coasts of Patagonia and the neighboring islands. The bathymetric range is from the shore to 600 fathoms. A specimen in the National Museum, which was obviously collected many years ago, is labelled "Navigator Islands."

Austrocidaris nutrix.

Cidaris nutrix Wyville Thomson, 1876, Journ. Linn. Soc. London, **13**, p. 62.

Fig. 4, p. 63, Journ. Linn. Soc. London, 13, Wyville Thomson, 1876.

There can be little question that this species is quite distinct from the preceding. Like it, however, it shows considerable diversity in color and the length of the primaries; some specimens are almost black, with light-colored primaries, while others have the test and secondaries, as well as the primaries, very light colored. Mortensen (**:03**) asserts, without offering any evidence to support his view, that the specimens collected by the "Challenger" at stations 147, 153 and 156 are not this species because the water was too deep at those stations for a shallow water species like *nutrix*. In view of the fact that a number of echinoderms are known with a very great bathymetric range, we can hardly consider the argument conclusive. The largest specimen of *nutrix* at hand is only 30 mm. h. d., but the primaries are 66 mm., while a specimen 26 mm. h. d. has primaries only 18 mm. This species appears to be confined to Crozet, Heard, and Kerguelen Islands, and the neighboring seas.

Austrocidaris mortenseni.

Goniocidaris mortenseni Koehler, 1902, Belgica Ech. et Oph., p. 5.

Figs. 1, 11, 17, 29, 30, Belgica Ech., Koehler, 1902.

It is quite possible that this species does not belong here, but so far as can be judged from the description and figures given it is most nearly allied to the foregoing species. Koehler says nothing about the secondaries, and as the primaries are very long, it is possible that the secondaries are not especially peculiar. The largest specimen was 26 mm. h. d., with primaries 60 mm. The color of the test and secondaries is very dark, while the primaries are reddish. Koehler says there was no indication that the species is "viviparous," but as he only had a single mature specimen, and that possibly a male, further light is needed on this point. The specimens were collected by the "Belgica" in the Southern Ocean, near 70° S. latitude and 87° E. longitude, in depths of 55–330 fths.

CENTROCIDARIS.

Centrocidaris A. Agassiz, 1904, Pan. Deep Sea Ech., p. 32.

Test very flat, vertical diameter generally less than .50 h. d.; coronal plates 7 or 8; areolae very little sunken; median interambulacral areas narrow, a little sunken, and bare; ambulacra very broad, .55–.60 of interambulacra; poriferous zones little or not at all sunken; median ambulacral area broad, flat, or somewhat depressed, with a double marginal series of tubercles, outer much larger; intervening space bare, or each ambulacral plate may carry an additional miliary tubercle; pores very large, nearly or quite horizontal; distance between two about equal to diameter of pore; surface of interval slightly elevated. Abactinal system moderate, .45–.50 h. d., with few (about 100) tubercles; genital plates much higher than wide, narrow, and bluntly-pointed externally; oculars entirely excluded from anal system, very wide and low but sharply pointed, with a markedly concave outer margin. Actinostome, .40–.45 h. d. Primary spines straight, cylindrical, slender, and nearly or quite smooth, about equal to h. d. or somewhat longer; actinal primaries not peculiar save for a wide collar; secondaries flat, thin, and narrow. All three kinds of pedicellariae usually present; large globiferous ones of two quite distinct sorts, one with broad, flat valves and neither lip nor end-tooth, the other with curved valves (like Cidaris), but with a prominent end-tooth and lip.

This monotypic genus was established for a very interesting and handsome cidaroid taken by the "Albatross" in 1891 off Cocos Island, 52 fths. In 1904–05, the "Albatross" obtained a dozen additional specimens near Hood Island, Galapagos, 100–300 fths., so that it is now possible to diagnose the genus fully. It is quite distinct from Goniocidaris, though it resembles it in the broad ambulacra, but it is doubtful if it is nearer to any other known genus.

Centrocidaris doederleini.

Goniocidaris Doederleini A. Agassiz, 1898, Bull. M. C. Z., **32**, 5, p. 73.
Centrocidaris Doederleini A. Agassiz, 1904, Pan. Deep Sea Ech., p. 33.

Plate 14, figs. 1, 2, Pan. Deep Sea Ech., A. Agassiz, 1904.

In young specimens the primary spines are very white and shining, and have 8–10 slightly elevated, glassy, longitudinal ridges, but these practically disappear with age and the spines become dull and yellowish. In alcoholic specimens the secondaries are green, slightly tipped with dark yellow, while the test is greenish with the lines between the genital and ocular plates and the bare spaces of ambulacra and interambulacra deep purplish or dull red. The largest specimen is 28 mm. h. d. and the longest spines measure 33 mm.

APOROCIDARIS.

Aporocidaris A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 36.

Test flattened, .50–.60 h. d. (but abactinal system sometimes so much elevated that vertical diameter from centre of anal system, .60–.80 h. d.), rather thin and fragile; coronal plates 6, rarely 7; areolae only slightly sunken; median interam-

bulacral area rather wide, bare, and slightly sunken along sutural line; ambulacra about .30 of interambulacra; poriferous zones almost flush with test; ambulacral plates few, 30–32 in largest specimens; median ambulacral area somewhat wider than a poriferous zone; each ambulacral plate is vertically wide and carries only a single tubercle, except in large specimens, when a second smaller tubercle is present and then vertical suture is obscured; pores very close together, somewhat oblique. Abactinal system very large, .60–.70 h. d., either flat or more or less elevated, with few or many tubercles. Actinostome .40–.50 h. d., consequently only .60–.80 of abactinal system, and notable for small number of plates borne by membrane, more or less of which near outer margin is quite bare. Primary spines slender, straight, and cylindrical, very finely prickly, white or nearly so, 1.5–3 h. d.; actinal primaries either coarsely or finely serrate or entire; secondaries and miliaries alike, cylindrical or club-shaped, blunt and more or less erect, rather scattered. Pedicellariae of only one kind, globiferous, but very variable in size.

The affinities of this interesting genus are rather obscure, for although the secondary spines resemble those of *Austrocidaris nutrix*, it is hard to believe that there is any close relationship to that species. There are no other living species of Cidaridae which approach sufficiently near the three rare species placed here to give us any real clue to their natural position. Although *A. milleri* has actinal primaries similar to those of Porocidaris, there is little else to ally it with that genus, and the other two species are even more different. The large abactinal system, few ambulacral plates, unsunken poriferous zones, somewhat bare actinostome, and the primary spines are striking reminders of Salenia. Two of the species are discoveries made by the "Albatross" and are found only in the deep waters of the Pacific Ocean; although *milleri* was once taken in 465 fths., most of the specimens are from over 1,600 fths. and *fragilis* has been taken only at depths exceeding 1,500 fths. The third species was found by the "Belgica" in much shallower water, but in the far Antarctic Ocean. The following key is based on the examination of 116 specimens of the two "Albatross" species.

Key to the Species.

Test moderately high, .55 h. d. and more; abactinal system elevated, with numerous tubercles (250–300 on a system 13 mm. across); ambulacral plates about 20, in a specimen 15 mm. h. d. . . . . *milleri*

Test flat, about .50 h. d.; abactinal system not elevated, with comparatively few tubercles (100–200 on a system 13 mm. across); ambulacral plates about 15, in a specimen 15 mm. h. d.

Color reddish- or yellowish-brown; arctic . . . . *fragilis*

Color bay or reddish; antarctic . . . . *incerta*

Aporocidaris milleri.

Porocidaris Milleri A. Agassiz, 1898, Bull. M. C. Z. **32**, 5, p. 74.

Aporocidaris Milleri A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 37.

Plate 6, Pan. Deep Sea Ech., A. Agassiz, 1904.

The test of this species is grayish, sometimes with a purple tinge, or yellowish, and the secondaries are of about the same color or paler. The primaries are

nearly or quite white. The largest specimen is 31 mm. h. d., while the primaries are sometimes 75 mm. long. The abactinal system is often elevated 3 or 4 mm. above the test. The "Albatross" collected this species in 1891, in the deep water between Acapulco and Panama, and the Galapagos, 465–1880 fths., while in 1904–05 she found it common in the still greater depths south and southwest of the Galapagos, 2005–2153 fths.

Aporocidaris fragilis.

Aporocidaris fragilis A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 37.

Plate 23, figs. 5–8, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

Of this species, the only known specimens, the largest of which is 23 mm. h. d., with primaries over 40 mm. long, were taken by the "Albatross" in the North Pacific, south of Alaska and southwest of Kamchatka in 1557–1973 fths.

Aporocidaris incerta.

Porocidaris incerta Koehler, 1902, Belgica Ech. et Oph., p. 7.

Figs. 2, 16, Belgica Ech., Koehler, 1902.

Koehler's supposition that this species is related to *milleri* is quite correct, though in the shape of the test it is more like *fragilis*. The position of *incerta* in this genus is confirmed not only by Mortensen's (:**03**) examination of the pedicellariae, but by a careful comparison of Koehler's description, with a specimen of *fragilis* of the same size (15 mm. h. d.) as his largest specimen. It is difficult to make out from that description just how much difference there is between the Arctic and Antarctic species. The latter was taken by the "Belgica" about 20 degrees south of Kerguelen Island, in 55–165 fths.

Stereocidaris.

Stereocidaris Pomel, 1883, Class. Meth. Gen. Ech., p. 110.

Test very similar to Dorocidaris, but usually flatter (.50–.60 h. d.), with fewer coronal plates (4–7, rarely 8 or 9) and relatively fewer primary spines (3–7, rarely 8, in each vertical series); that is to say, uppermost coronal plate without primary spine, and second often, third very rarely, similarly bare. Abactinal system large (.35–.55 h. d., usually about .50), often convex, and noticeably thick and stout, but this character varies much within a single species; abactinal miliaries and secondaries usually very small, but this character also varies much. Primary spines usually flaring at tip, or if tapering, provided at base with conspicuous buttress-like "wings"; "winged" primaries are usually noticeably compressed, but otherwise primaries are cylindrical. Globiferous pedicellariae, large and small, commonly lack a conspicuous end-tooth on valves.

This is the most poorly defined and unsatisfactory genus in the family, and yet the species contained in it have something about their general appearance which is distinctive and makes it possible to recognize them usually at a glance. They show considerable diversity in test, spines, and pedicellariae, and some individuals are strikingly like Dorocidaris. It is only when a considerable amount

of material is available for comparison that such individuals can be properly placed. Unfortunately in preparing the following key there have been available only five species, represented by 69 specimens, and it is probable that errors have crept in which might have been avoided had a larger series of specimens been available. However, Anderson's and Doderlein's descriptions and figures are sufficiently complete and accurate to make it possible to include their species. Döderlein's (:06) measurements and figures have been of the greatest help. The Japanese species need revision based on plenty of material, and it is possible that the three species here recognized will prove to be simply forms of a single species, as the differences between them are slight. All the recent species occur in depths of 40 fathoms or over, and all but one (*ingolfiana*) are found only in the Indo-Pacific region. A number of fossil species from the Cretaceous are referred to this genus. How Döderlein (:06) can lay great stress on the form of the pedicellariae in Stereocidaris and write without qualification "Grosse und kleinere globifere Pedicellarien ohne unpaaren Endzahn" (p. 102), is incomprehensible, for his own figures (Plates XXXVI and XXXVII) contradict the statement flatly. Had I examined no specimens, the study of Döderlein's figures would have satisfied me that the pedicellariae are no more reliable than the spines.

Key to the Species.

Actinostome very small, .20–.35 h. d., usually under .30 except in young specimens.

Primary spines often more or less trigonal, but seldom with three conspicuous "wings" near base; tridentate pedicellariae wanting; pedicels contain perforated plates besides thorny curved rods.

Longest primary spines, 1.3–2.7 h. d., thickness commonly less than 8% of length; perforated plates in pedicels small, with few large holes . . . . *indica*

Longest primary spines about 1.35 h. d., thickness about 10% of length; perforated plates in pedicels broad, with many small holes . . . *capensis*

Primary spines commonly with three conspicuous wings near base; tridentate pedicellariae common; pedicels with few or no perforated plates . . . . *tricarinata*

Actinostome larger, almost always over .35 h. d.

Primaries pale pink or reddish, with 10–16 longitudinal series of fine prickles, which often merge into ridges, and 1 (or more) of these becomes a conspicuous "wing" or "buttress" on basal half of spine, which is also often flattened; primaries tapering towards tip; coronal plates 5 or 6 (rarely 7).

Abactinal system coarsely tubercled; median ambulacral area depressed and bare along vertical suture, each plate with only 1 or 2 tubercles; color of test and secondaries madder purple . . . *alcocki*

Abactinal system with numerous small tubercles; median ambulacral area not depressed, often elevated along vertical suture, which is seldom visible, crowded with tubercles, each plate with 4–6; color of test and secondaries brownish, usually very pale; no tridentate pedicellariae . . . . *ingolfiana*

Primaries cylindrical, at least near base, never provided with "wings," but with more or less evident, longitudinal series of rounded or sharp granules, tending to become ridges near tip of spine, which is often flaring.
  Ambulacra very narrow, only .18–.25 of interambulacra, not deeply sunken; median area closely covered with 6 series of tubercles; all miliaries very minute; neck of primaries white . . *microtuberculata*
  Ambulacra .25–.33 of interambulacra in width.
    Secondaries not white; actinostome much smaller than abactinal system; tridentate pedicellariae present.
      Abactinal system elevated 10% or more above test; abactinal surface appears very bare from small, wide, closely appressed miliaries; primaries not white with purple collar . . . . *grandis*
      Abactinal system flat or little elevated; abactinal surface well covered with ordinary miliaries; primaries when perfectly clean, white, usually with a distinct purple collar . . . *leucacantha*
    Secondaries white or whitish; actinostome nearly equal to abactinal system; no tridentate pedicellariae . . . . . . *sceptriferoides*

Stereocidaris indica.

Stereocidaris indica Döderlein, 1901, Zoöl. Anz., **23**, p. 19.

Plate 10, figs. 1, 2; Plate 11, Deutsche Tiefsee Exp. Ech., Döderlein, 1906.

This species appears to be very variable, and Döderlein (**:06**), recognizes four varieties (*integra*, *africana*, *carinata*, *sumatrana*), based upon slight differences chiefly in primary spines and pedicellariae. He says, however, that he doubts the constancy of any of these varieties except *sumatrana*, which appears to be well-marked. Döderlein's admirable descriptions and his tables of measurements are all that could be desired, but the figures given often suffer from indistinctness; they are quite good enough, however, to reveal the notable diversity in the pedicellariae of this species. The color is yellowish, each of the larger secondaries with a dark spot and the actinal primaries white. The largest specimen measured 46 mm. h. d. The distribution of *indica* is from Somali-Land to the Moluccas, in 443–715 fths.

Stereocidaris capensis.

Stereocidaris indica var. *capensis* Döderlein, 1901, Zoöl. Anz., **23**, p. 19.
Stereocidaris capensis Döderlein, 1906, Deutsche Tiefsee Exp. Ech., p. 110.

Plate 10, figs. 3–6, Deutsche Tiefsee Exp. Ech., Döderlein, 1906.

Although closely related to the preceding species, Döderlein considers the South African form entitled to specific rank. As he finds the chief and most constant character in the calcareous plates of the pedicels, the species seems to me open to serious doubt, for I do not consider that any importance can be attached to the exact form of the microscopic, calcareous particles of the Echini. The only known specimens of *capensis* were taken by the "Valdivia"

off Cape Colony in 278 fths. The largest measured 36 mm. h. d. The color is gray, with a brownish tinge, the secondaries with darker tips, and the actinal primaries whitish.

Stereocidaris tricarinata.

Stereocidaris indica var. *tricarinata* Döderlein, 1901, Zoöl. Anz., **23**, p. 20.
Stereocidaris tricarinata Döderlein, 1906, Deutsche Tiefsee Exp. Ech., p. 112.

Plate 9, Deutsche Tiefsee Exp. Ech., Döderlein, 1906.

This species seems to be rather better defined than *capensis*, but as its validity depends largely on the value assigned to certain features of the pedicellariae, there is still room for some doubt as to its proper standing. The deformed specimen to which Döderlein has given the varietal name *teretispina* is indeed very different from the typical form, but as it was a parasitized individual, its peculiarities may be pathological. The "Valdivia" collected *tricarinata* only in the vicinity of Sumatra in 206–417 fths. The largest specimen was 54 mm. h. d. The color of the test is dark reddish; the primaries are gray with rosy necks; the actinal primaries whitish; the larger secondaries have a dark spot.

Stereocidaris alcocki.

Dorocidaris alcocki Anderson, 1894, Journ. Asiat. Soc. Bengal, **63**, pt. 2, 3, p. 191.

Plate 5, figs. 3, 3a, Ill. Investigator Zoöl. Ech., Alcock and Anderson, 1895.

There can be little question of the validity of this species unless *indica* proves to be even more variable than is supposed. If the published descriptions are accurate (and there is no apparent reason for doubting them), the two species are quite distinct. The "Investigator" took *alcocki* in the Laccadive Sea in 636 fths. It is a small species, only 25–26 mm. h. d.

Stereocidaris ingolfiana.

Stereocidaris ingolfiana Mortensen, 1903, Ingolf-Exp. Ech., **1**, p. 38.

Plate 6, figs. 1–5, 11, Ingolf-Exp. Ech., Mortensen, 1903.

It is rather curious that this very distinct and interesting species should not have been described until so recently, for adult specimens are easily distinguished from any other North Atlantic or West Indian species. Even when the primary spines are missing or do not have the "wings" developed, the species may be recognized by the very numerous slender secondaries and miliaries, and the more or less elevated median ambulacral area, densely covered with minute tubercles. Mortensen's description lacks nothing, but in the table of measurements it is evident that "height" is estimated in some variable way; for while in a large series of tests of such a variable species as *D. papillata*, for example, there is sometimes a variation of 20% in the vertical diameter, Mortensen's measurements would indicate a variation of 30% among 8 specimens of *ingolfiana;* and while *papillata* is occasionally .75 h. d. in height, Mortensen gives one speci-

men of *ingolfiana* over .90 h. d., or, in other words, almost spherical! The specimens in the Museum of Comparative Zoölogy are .54–.58 h. d., while Mortensen's table gives .61–.91 h. d. as the range for his 8 specimens; it can hardly be doubted that this difference is due to the method of measurement used. In the diameter of the abactinal system and the actinostome, Mortensen's figures, .41–.54 h. d. for the former and .36–.40 h. d. for the latter, accord well with the measurements of the specimens in the Museum of Comparative Zoölogy. One error in his table occurs which may be either a slip of the pen or a misprint; the specimen 28 mm. h. d. is said to have the abactinal system only 10.5 (the same as the actinostome), while examination of the figure given on Plate 6 (which is apparently that specimen) shows the abactinal system to be about 14 mm., which is what would be expected. The largest specimen recorded is 35 mm. h. d.; the color is brownish, but not at all distinctive. The geographical range is from Iceland to Nevis, in 165–665 fths.

Stereocidaris microtuberculata.

Cidaris (*Stereocidaris*) *microtuberculata* Yoshiwara, 1898, Ann. Zoöl. Jap., **2**, pt. 2, p. 57.

Plates 1 and 2.

Although this species is closely allied to the following, it is easily distinguished by the characters given in the key. The test and small spines are yellowish-brown with a greenish tinge, and the larger secondaries have a median, longitudinal stripe of a darker shade. The fully developed primaries, when clean, are white. This is the biggest member of the genus, the diameter of the largest known specimen being 86 mm.

Stereocidaris grandis.

Dorocidaris grandis Döderlein, 1885, Arch. Naturg., **51** Jhrg., 1, p. 77.
Stereocidaris grandis Döderlein, 1887, Jap. Seeigel, p. 42.

Plate 1, Plate 2, figs. 1–11, Jap. Seeigel, Döderlein, 1887. Plates 33, 36, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

The series of specimens at hand from Japan and Hawaii shows that this is a well-characterized but somewhat variable species. The primaries are quite stout (the thickness 5–7% of the length), usually deep pinkish, especially at base, but often brown, gray, or green, while the test is gray, yellowish, or greenish, and the secondaries yellowish or greenish, often with a broad, longitudinal green stripe; the general effect is greenish, more or less inclined towards yellowish. The largest specimen in the series is 40 mm. h. d., but Döderlein's largest specimen was 61 mm. Specimens of *grandis* are known not only from Japan and Hawaii, but also from the Dutch East Indies (de Meijere: **04**). It is possible that those to which de Meijere refers as having "die Halse" "hell violet" are really to be referred to the next species.

Stereocidaris leucacantha.

Stereocidaris leucacantha A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 23.

Plates 15, 32, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

Although this Hawaiian species, collected at a number of stations by the "Albatross," is very close to *grandis* in many ways, the two are easily distinguished at a glance, and no intermediate specimens have been seen. The largest specimen is 57 mm. h. d. The color is somewhat variable, that of the test and secondaries ranging from almost yellowish-white to deep purplish-gray; there is usually a decidedly purple cast actinally. The primaries are longer and more slender than in *grandis* (the thickness only 4 or 5% of the length), and are white when clean. The fully grown ones almost always have the collar deep purple, sharply contrasted with the white neck. In many specimens the secondaries show an evident green tinge.

Stereocidaris sceptriferoides.

Cidaris (Stereocidaris) sceptriferoides Döderlein, 1887, Jap. Seeigel, p. 5.
Stereocidaris sceptriferoides Döderlein, 1887, Jap. Seeigel, p. 42.

Plate 2, figs. 12–17, Jap. Seeigel, Doderlein, 1887.

This species, although it appears to be very rare, is well characterized. The globiferous pedicellariae are very slender, the valves often have a conspicuous end-tooth, and the opening may be very long and narrow. The only known specimens of this species were taken in Japanese waters.

ANOMOCIDARIS.

Anomocidaris A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 30.

Test rather flat, vertical diameter about .50 h. d., but sometimes, through elevation of abactinal system, conspicuously rounded-conical; vertical diameter from centre of anal system in such cases being about .60 h. d.; coronal plates 7–9; areolae abactinally small, very shallow and indistinct, on the uppermost plates practically wanting, but at ambitus and below deeply sunken and merging together near actinostome; median interambulacral area covered with small tubercles, not at all bare or sunken, but sutural lines distinct; ambulacra about .30 of interambulacra; poriferous zones not deeply sunken; median ambulacral area with two or three series of tubercles on each side, inner much smaller and more or less incomplete; vertical sutural line usually distinct; pores nearly horizontal; distance between two not quite equal to diameter of pore. Abactinal system moderate, about .47 h. d.; anal system small, less than .40 of abactinal system and composed of only about 20 plates and grains; oculars rather small and genitals very widely in contact with each other. Whole abactinal surface more or less densely covered with very small secondaries, miliaries, and pedicellariae. Actinostome small, .35 h. d., only about .75 of abactinal system. Primary spines slender, 1–1.50 h. d.; thickness 3–5% of length; cylindrical with longitudinal series of minute granules, sometimes nearly smooth, often flattened and widened at tip; actinal primaries very variable, some-

times flattened, curved, and entire, slightly notched or even serrate, but frequently thick, straight, and more or less smooth; secondaries flat, those on ambulacra quite narrow. Large globiferous sometimes, and tridentate pedicellariae always, wanting; small ones sometimes with, more often without, end-tooth on valves.

The above diagnosis of this interesting monotypic genus is based on a large series of specimens, 11–40 mm. h. d., which admits of little question of the identity of Döderlein's *St. japonica* and Yoshiwara's *C. tenuispinus*. Some of the peculiarities are given by those writers in their original descriptions of the only species, which they regarded as a Stereocidaris. While its nearest relatives are probably to be found in that genus, it is quite distinct from them and is well entitled to generic rank. For a full discussion of this genus and its type species, see A. Agassiz and Clark, 1907, Bull. M. C. Z., **51**, p. 112–114.

Anomocidaris japonica.

Dorocidaris japonica Döderlein, 1885, Arch. Naturg., **51** Jhrg., 1, p. 76.
Stereocidaris japonica Döderlein, 1887, Jap. Seeigel, p. 34.
Cidaris (*Stereocidaris*) *tenuispinus* Yoshiwara, 1898, Ann. Zoöl. Jap. **2**, pt. 2, p. 57.
Anomocidaris tenuispina A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 30.
Anomocidaris japonica. A. Agassiz and Clark, 1907, Prelim. Rep. Albatross 1906 Ech., Bull. M. C. Z., **51**, p. 112–114.

Plate 31, figs. 5–8, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907. Plate 3, Jap. Seeigel, Döderlein, 1887.

The only known specimens of this species have been taken in Japanese waters, in 40–284 fths. The largest specimen is 40 mm. h. d. The color of test and secondaries is commonly some shade of brown, often reddish, sometimes greenish, while the primaries are grayish or brownish, often with a decidedly olive-green tinge, rarely rosy-reddish; the neck is brown, usually polished and shining.

ACANTHOCIDARIS.

Acanthocidaris Mortensen, 1903, Ingolf-Exp. Ech., **1**, p. 21.

Test high, .60–.70 h. d.; coronal plates 7 or 8; areolae not at all sunken and very distinct, even actinally; median interambulacral area somewhat sunken and bare along vertical suture; ambulacra about .25 of interambulacra; poriferous zones little sunken; each ambulacral plate slightly curved, with a single large tubercle near upper margin of median portion, a much smaller one near lower margin halfway to inner end, and a very minute one (which usually carries a pedicellaria) just beneath largest; this arrangement is remarkably constant, regardless of age and size; it is well shown in a specimen 9 mm. h. d., and is not essentially different in one 52 mm. h. d.; in some very large specimens, however, another small secondary tubercle may be borne on inner end of plate; median vertical suture usually visible, but there is no noticeable median bare strip; pores oblique much as in Cidaris. Abactinal system about .45 h. d., very flat; peculiar in that all oculars are broadly

in contact with anal plates except right anterior one; this ocular is wholly or very nearly excluded; instead of being an individual peculiarity (as sometimes occurs in Tretocidaris *et al.*), this curious arrangement is remarkably constant, and is as evident in a specimen 17 mm. h. d. as in those over 40 mm. Actinostome .35–.40 h. d., generally about .90 of abactinal system. Primary spines unique, 2.5–3.3 h. d., straight or somewhat curved, nearly smooth; base broad and depressed, somewhat triangular in cross-section, with more or less evident traces of longitudinal series of granules, but in large specimens these are scarcely visible; collar enormously wide, .20 or more of length of spine, and abruptly contrasted with remainder in color; this remainder bears 10–20 sharply distinct longitudinal ribs, which are seemingly continuations of series of granules on collar; outer limit of collar not straight, *i. e.* forming a ring around spine, but more or less deeply concave on both sides, especially actinally; tip of primary blunt or more or less expanded; actinal primaries conspicuously capped and serrate as in Stephanocidaris, but much stouter than in that genus; secondaries long, slender, and flat. All three kinds of pedicellariae present; globiferous, both large and small, lack an end-tooth on valves; stalks of large ones usually with a "limb."

This notable genus will be recognized at first sight by the peculiar, handsome spines somewhat resembling those of Coelopleurus. The above diagnosis is based upon the examination of fifty fine specimens of *hastigera*, representing all ages. The type of the genus is the species named by Bell (**'93**) *curvatispinis*, but nothing is known of its test or abactinal system, for neither Bell nor Mortensen (**:03**) has attempted any description beyond spines and pedicellariae. It is interesting to find that the "Siboga" collected in the East Indies a third species of this genus, which de Meijere (**:04**) has named *Cidaris maculicollis.* His careful description of the primary spines leaves no doubt as to the proper relationship of this new form, although the describer, in spite of the primaries, places it in the same subgenus with *C. metularia, tribuloides,* etc., because he considers the large globiferous pedicellariae like those of Cidaris. As a matter of fact, however, the valve of a pedicellaria which de Meijere figures is quite as near Acanthocidaris as it is to typical Cidaris. On account of the broad collar and the serrate actinal primaries, de Meijere (**:03**) originally described *maculicollis* as a Porocidaris, but it really has as little in common with that genus as with Cidaris.

Key to the Species.

Collar of primary spines very light-colored, unspotted; remainder of spine reddish or brownish.
- Secondaries cream-color or yellowish; base of primaries with distinct angles, which may be somewhat serrate . . . . *curvatispinis*
- Secondaries dark reddish-brown; base of primaries with rounded angles, not in the least serrate . . . . *hastigera*

Collar of primary spines greenish, with red spots; remainder of spine whitish with 3 or 4 cross-bands of reddish . . . . *maculicollis*

Acanthocidaris curvatispinis.

Cidaris curvatispinis Bell, 1893, Trans. Zoöl. Soc., London, **13**, p. 303.
Acanthocidaris curvatispinis Mortensen, 1903, Ingolf-Exp. Ech., **1**, p. 29.

Plate 38, Trans. Zoöl. Soc. London, 13, Bell, 1893.

Nothing is known in regard to this species, except that Bell has figured the entire animal and Mortensen the pedicellariae. The type specimen in the British Museum, and a second specimen in Paris, are both from Mauritius and are the only ones known. The type specimen is about 50 mm. h. d., with primaries 150 mm. long; many of the latter are banded near the tip with brownish and yellowish.

Acanthocidaris hastigera.

Acanthocidaris hastigera A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 39.

Plates 37–42, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

In addition to the differences mentioned above, this species may be distinguished from the preceding by the stouter primaries and their entire lack of any cross-barring or bands of color. It was found by the "Albatross" to be common among the Hawaiian Islands. When cleaned, the test is nearly white in young specimens, with the median ambulacral area red, the actinostome decidedly green, and the abactinal system dull greenish-red; in older specimens the white is replaced by reddish-cream color, and there is little green evident anywhere. When uncleaned the test is, like the secondaries, dark brownish-red, much lighter in very young specimens. The largest specimen is 52 mm. h. d.; the longest primaries are 145 mm. All of the "Albatross" specimens were taken on sandy bottom in comparatively shallow water, 23–222 fths.

Acanthocidaris maculicollis.

Porocidaris maculicollis de Meijere, 1903, Tijdsch. Ned. Dierk. Vereen. (2) **8**, p. 1.

Plate 3, figs. 18, 19, Siboga-Exp. Ech., de Meijere, 1904.

The secondaries of this species are described as having "a dark longitudinal stripe," but the ground color is not mentioned. The four specimens collected by the "Siboga" were all small (10–18 mm. h. d) and were evidently young ones. They were taken at depths of only 39–53 fths, and at each of the three stations mussel-shells formed a characteristic feature of the bottom.

POROCIDARIS.

Porocidaris Desor, 1854, Syn. Ech. Foss., p. 46.

Test rather high, .60–.75 h. d.; coronal plates, 7–9; areolae more or less sunken and merging actinally; median interambulacral area with vertical sutural region somewhat sunken and bare; ambulacra .18–.34 of interambulacra; poriferous zones very little sunken; median ambulacral area with a single marginal row of tubercles,

and even this may be incomplete in small specimens; between are more or fewer scattered tubercles, but there is never a complete second series even in very large specimens; vertical sutural line, bare; pores oblique, close together, surface of interval rough or elevated. Abactinal system variable in size, oculars and especially genitals with noticeably wide bare margins. Actinostome .30–.45 h. d., with few or no interambulacral plates. Primary spines, when fully developed, long, 1.5–4 h. d. cylindrical or nearly so, white (sometimes tinged with rose, purple, or yellow) with a darker collar; actinal primaries flat, somewhat curved, coarsely and sharply serrate; secondaries flat and not peculiar. No globiferous pedicellariae whatever; tridentate pedicellariae very variable in size (.30–6.0 mm.) and form, with 2–4 (generally 3) unusually stout, wide valves.

This is one of the most distinct and easily recognized of the genera of recent Echini, but the species it contains are most perplexing and are exceedingly difficult to distinguish from each other. The genus has a wide geographical range, as it occurs in the North Atlantic Ocean, the Caribbean Sea, among the Galapagos Islands, the Hawaiian Islands, the East Indian Islands, and the Nicobar Islands, along the coast of Japan, near Australia, and along the east coast of Africa, it depths ranging from 169 to 799 fths. Several species from the Tertiary have been named, and serrate spines, like the actinal primaries of Porocidaris, occur in the Jurassic. There is little diversity of color in the genus, for the test, the collar of the primaries, and the small spines are commonly some shade of brown, often becoming very dark or deep purple with age, while the primaries are usually very white. The following key is based on the examination of 54 specimens representing all the species, except *misakiensis*.

Key to the Species.

Pedicellariae all with 2 valves . . . . *purpurata*

Pedicellariae mostly with 3 valves.

Abactinal system .40–.55 h. d.; primaries rather stout (thickness of large ones 3–6% of length), finely and sharply thorny. (These prickles are not always easily seen with the unaided eye, but are so distinct that a spine cannot be drawn upward between thumb and finger when lightly closed upon it.)

Small spines in interambulacra, outside scrobicular circles, above ambitus, very few; ambulacra almost wholly bare between marginal rows of tubercles; primaries stout, 1.5–2.5 h. d. (thickness 5–6 per cent of length), often becoming larger and fluted near tip, with numerous (25–30) longitudinal series of prickles . . . . *sharreri*

Small spines more numerous on upper half of test; ambulacra usually with scattered tubercles; primaries somewhat less stout, with about 12–15 longitudinal series of prickles, more or less tapering and never enlarged and fluted at tip, but occasionally with large projecting thorns near base.

Primaries less stout (thickness 3–4 per cent of length); no special depression on inner surface of valves of large pedicellariae above hypophysis; test, secondaries, and collar of primaries light reddish- or yellowish-brown . . . . *elegans*

Primaries stouter (thickness about 4.5 per cent of length); a distinct triangular impression on inner surface of valves of large pedicellariae above hypophysis; test, secondaries, and collar of primaries deep, dark brown . . . . *misakiensis*

Abactinal system .35–.45 h. d.; primaries very long and slender, 2.5–4 h. d. (thickness only 2–3 per cent of length); very nearly smooth (slip easily between thumb and finger).

Large pedicellariae always with 3 valves, which are distinctly pointed; anal system about .50 of abactinal; median ambulacral area about .37 of ambulacrum; size small, under 35 mm. h. d.; color pale, and primaries very white and shining . . . . *cobosi*

Large pedicellariae very variable, sometimes with only 2 or with 4 valves, which are usually broad and are rounded at tip; anal system about .45 of abactinal; median ambulacral area about .50 of ambulacrum; size large, up to 85 mm. h. d.; color usually very dark and primaries yellowish . . . . *variabilis*

Porocidaris purpurata.

Porocidaris purpurata Wyville Thomson, 1872, Ann. Mag. Nat. Hist., (4) **10**, p. 302.

Plate 59, Porcupine Ech., Wyville Thompson, 1875.

One needs only to compare a specimen of this cidaroid with any other member of the genus to reject Mortensen's (**:03**) proposed genus "Histocidaris," for aside from the pedicellariae, the only feature in which *purpurata* differs noticeably from the others is the presence of an exceptionally wide collar on *some* of the primaries of *some* specimens, and that can hardly be considered a very useful character. Moreover Mortensen's proposed variety *talismani,* which he thinks may even be a distinct species, cannot be recognized, for the primaries with swollen, fusiform, violet collars occur in typical *purpurata,* and one is figured by Thomson (**'75**), though they are not present in all specimens. The small spines and some of the abactinal primaries are light reddish- or purplish-brown. The largest recorded specimen is 50 mm. h. d. This species is known only from the North Atlantic, save for the specimen from the Nicobar Islands, collected by the "Valdivia," and referred to *purpurata* by Döderlein.

Porocidaris sharreri.

Porccidaris Sharreri A. Agassiz, 1880, Bull. M. C. Z., **8**, p. 71.

Plate 3, Blake Ech., A. Agassiz, 1883.

This handsome West Indian species was dredged by the "Blake" off Georgia in 279 fths. (in company with *St. ingolfiana*) and also near Barbados in 356 fths. The general color is red-brown and not at all purplish. The largest specimen is 69 mm. h. d., with spines 114 mm. long.

Porocidaris elegans.

Porocidaris elegans A. Agassiz, 1879, Proc. Amer. Acad., **14**, p. 198.

Plate 3, Challenger Ech., A. Agassiz, 1881.

Originally collected by the "Challenger" off New South Wales and southeast from the Philippines, specimens of Porocidaris, referred to this species, have since been taken by the "Valdivia" near Sumatra, and off the east coast of Africa, and by the "Siboga" among the Dutch East Indies. One of the specimens collected by the latter vessel measured 85 mm. h. d. The specimen from the Bay of Biscay reported by Koehler (**'96**) is doubtless not this species; but probably *purpurata*, though it might be *sharreri*, with which species *elegans* agrees in coloration and many other points. The 5 specimens taken by the "Siboga" which de Meijere (**:04**) calls "*Cidaris elegans juv.?*" are rather peculiar, especially the pedicellariae, and their real relationship is doubtful. The specimens taken by the "Valdivia" differ from *elegans*, not only in their remarkably light coloration, but in their small abactinal system, actinostome and anal system, the very thorny primaries, and their large number of coronal plates. It is quite likely that they are a distinct species.

Porocidaris misakiensis.

Cidaris (*Porocidaris*) *misakiensis* Yoshiwara, 1898, Ann. Zoöl. Jap., **2**, pt. 2, p. 58.

Plate 2, fig. 16, Siboga-Exp. Ech., de Meijere, 1904.

This is the most dubious species of the genus, especially as no complete description or figures have appeared. Aside from the original preliminary description, the only available information about *misakiensis* is contained in de Meijere's "Siboga" report (**:04**). He found one specimen which might be referred to this species, but the difference between it and *elegans* is difficult to understand, and it will be surprising if the two prove to be really distinct. Yoshiwara's specimen was 39 mm. h. d., and de Meijere's was 50 mm. The color is said to be dark brown.

Porocidaris cobosi.

Porocidaris cobosi A. Agassiz, 1898, Bull. M. C. Z., **32**, 5, p. 74.

Plate 9, Pan. Deep Sea Ech., A. Agassiz, 1904.

This is the handsomest species of the genus, and except *purpurata*, the easiest to recognize. It has been taken only once, and then by the "Albatross," near Chatham Island, Galapagos, on a rocky bottom in 385 fths. The largest specimen is only 35 mm. h. d.

Porocidaris variabilis.

Porocidaris variabilis A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 32.

Plates 16–22, 23, figs. 1–4, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

This species was found by the "Albatross" to be common among the Hawaiian Islands, and some very fine specimens were secured. The largest is deep purple, and measures 85 mm. h. d.; the others are various shades of brown, and one was very light-colored, like *cobosi*. It is possible that if *misakiensis* is really distinct from *elegans*, this species may prove to be identical with Yoshiwara's.

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EXPLANATION OF PLATES.

PLATE 1.

Stereocidaris microtuberculata Yoshiwara. Nat. size.
Abactinal view.

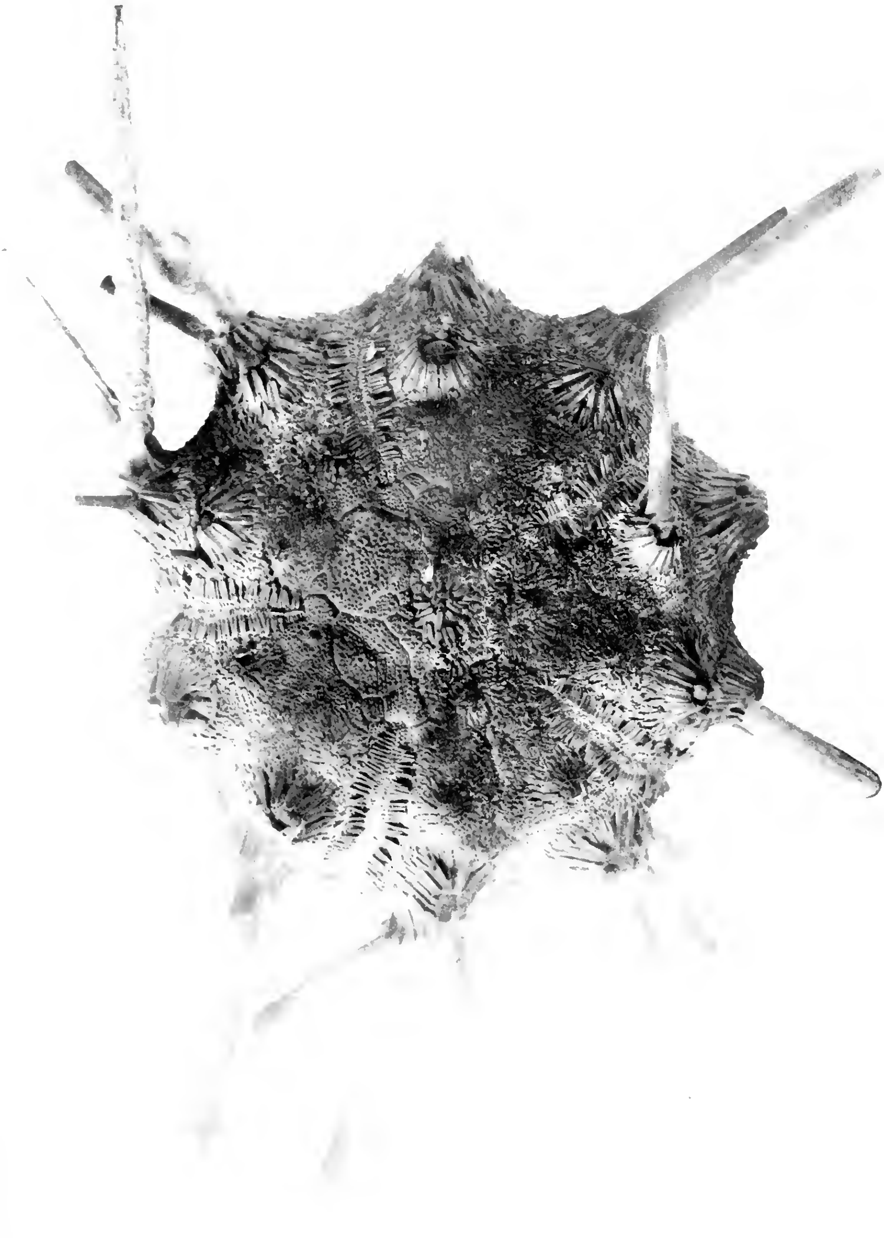


PLATE 2.

Stereocidaris microtuberculata Yoshiwara. Nat. size.
Side view of same specimen as Plate 1.

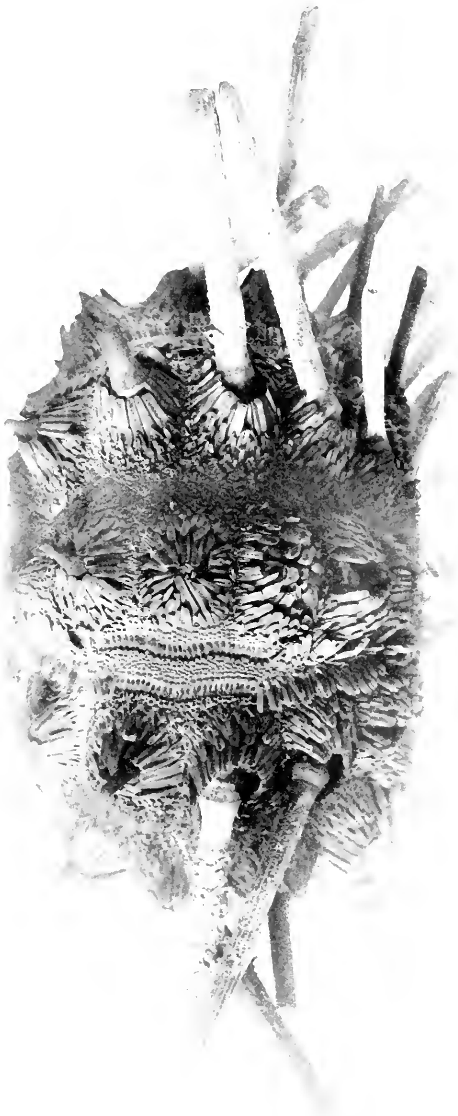
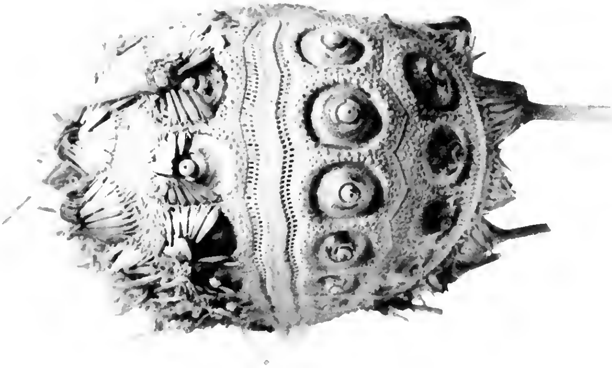


PLATE 3.

Calocidaris micans (Mortensen). Nat. size.

1. Ambulacral view of partly cleaned specimen ; all primary spines broken.
2. Abactinal view of same.



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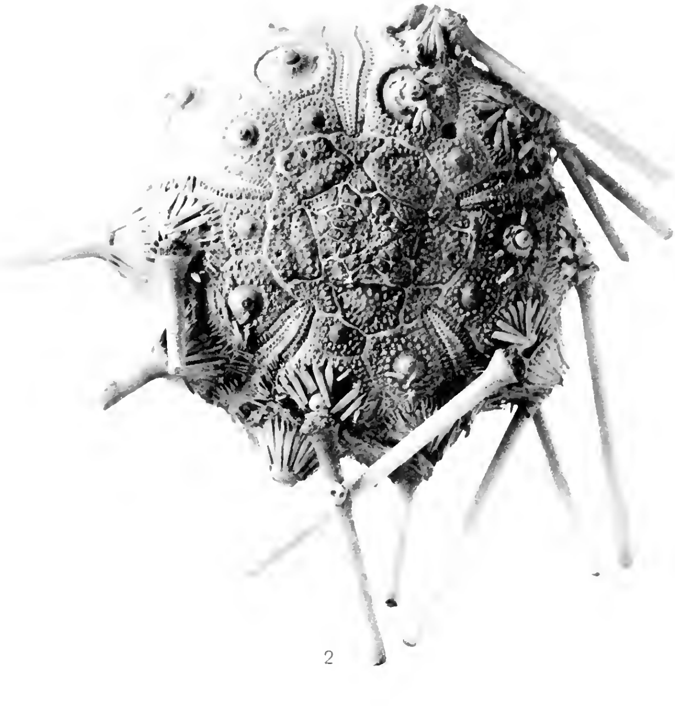

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PLATE 4.

Dorocidaris rugosa, sp. nov. Nat. size.
Abactinal view.

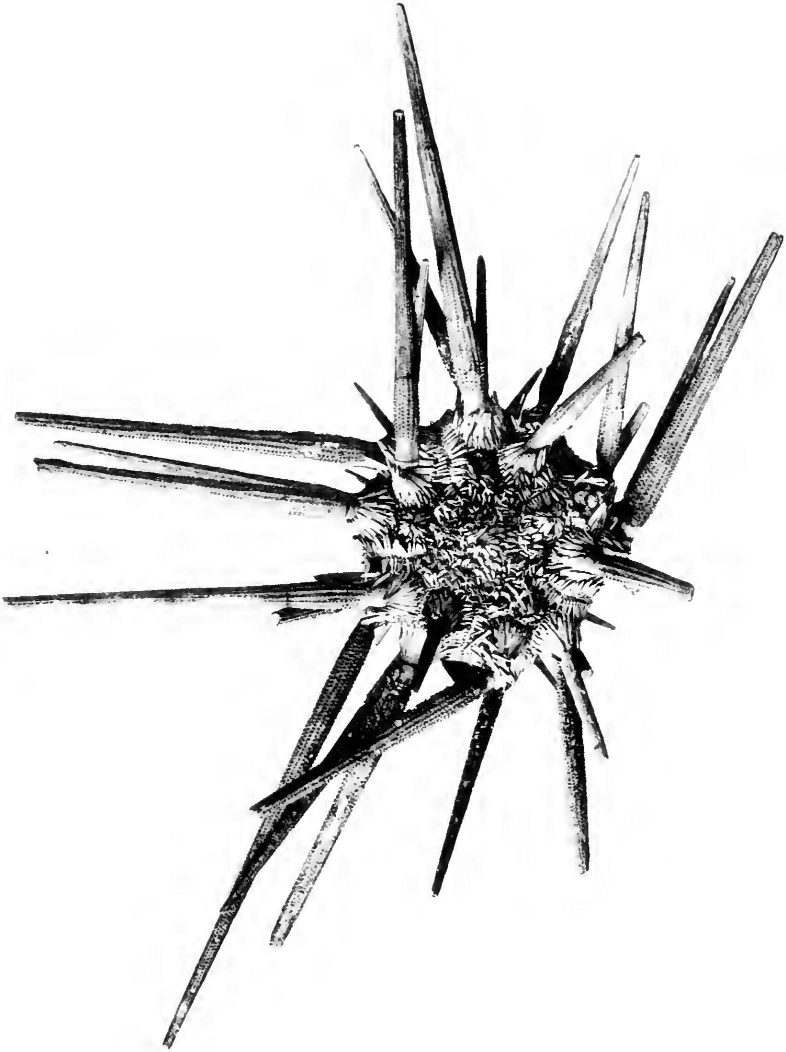

PLATE 5.

Dorocidaris rugosa, sp. nov. Nat. size.
Actinal view.

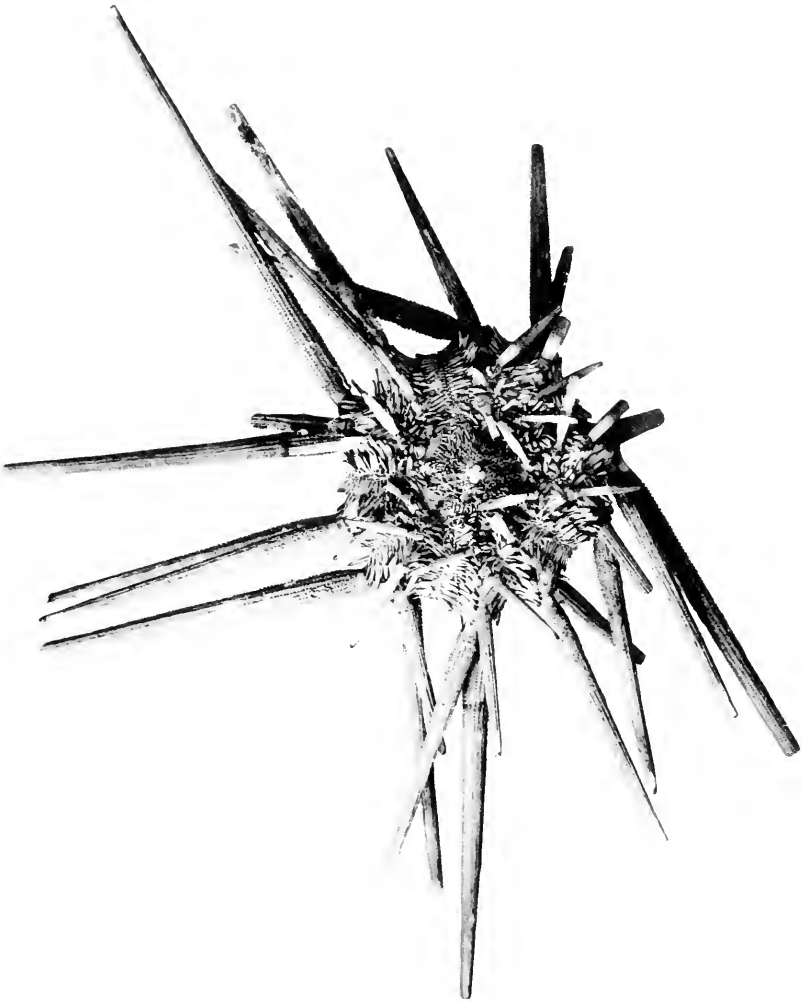

PLATE 6.

1–2. Tretocidaris perplexa, sp. nov. Nat. size.
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    2. Actinal view.

3–4. Tretocidaris dubia, sp. nov. Nat. size.
    3. Abactinal view of partly cleaned specimen.
    4. Actinal view of same.

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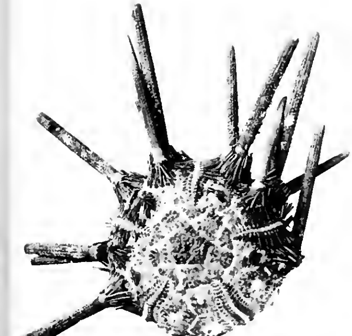

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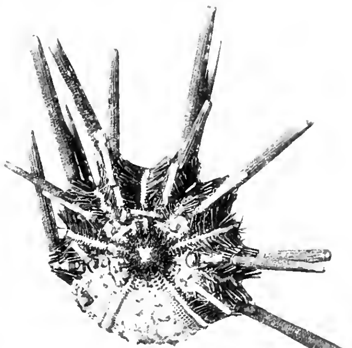

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PLATE 7.

1–4. Tretocidaris perplexa, sp. nov. Nat. size.
1. Abactinal view of partly cleaned specimen.
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5. Abactinal view of partly cleaned test.
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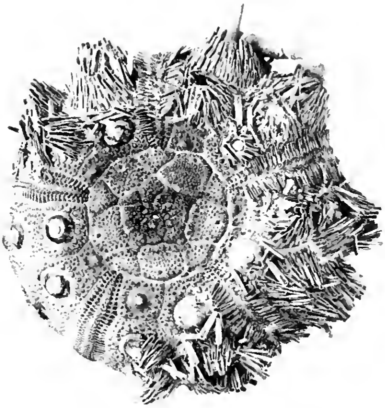
7. Interambulacral view of same.
8. Ambulacral view of same.



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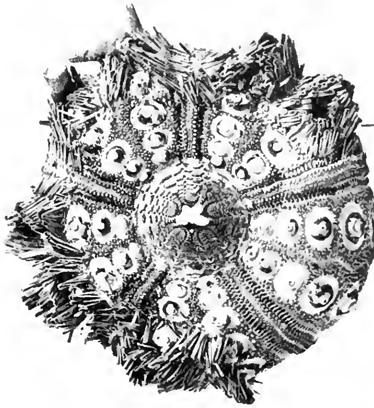

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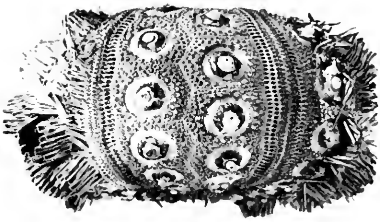

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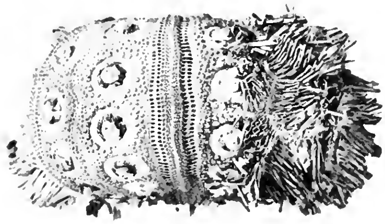

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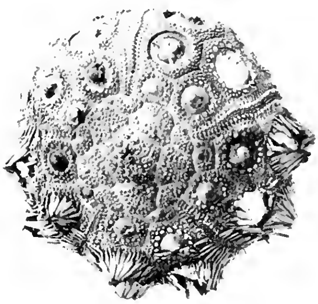

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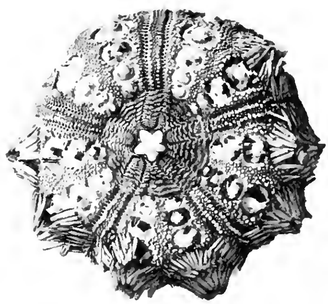

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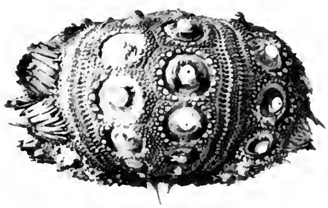

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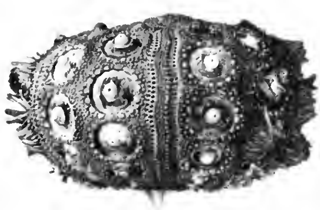

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PLATE 8.

Tretocidaris bartletti (A. Agassiz). Nat. size.
Abactinal view of specimen with cylindrical spines.

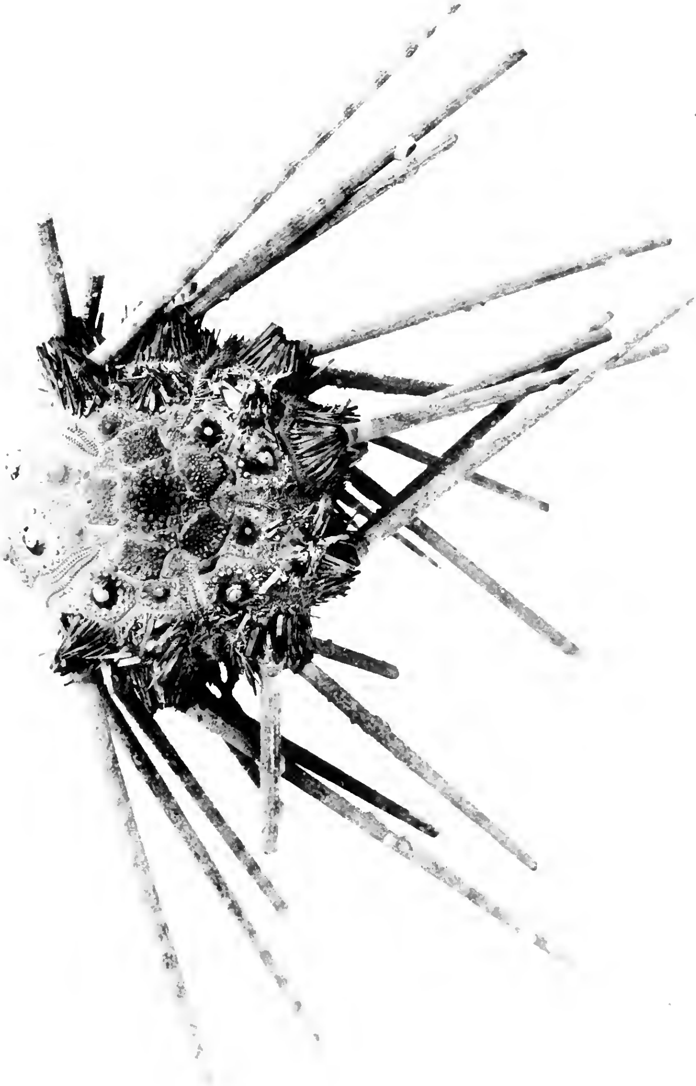
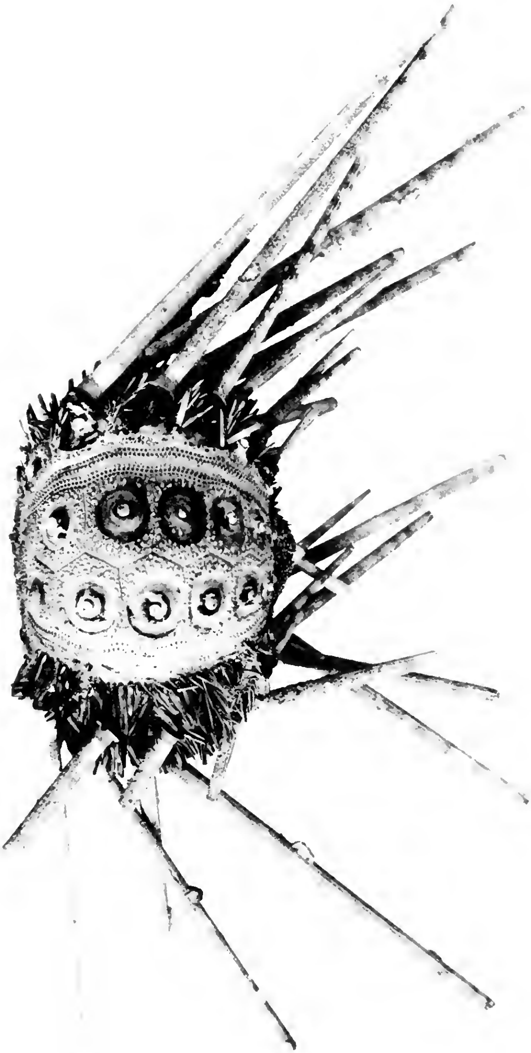


PLATE 9.

Tretocidaris bartletti (A. Agassiz). Nat. size.
Interambulacral view of same specimen as Plate 8.



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1–2. Tretocidaris bracteata (A. Agassiz). Nat. size.
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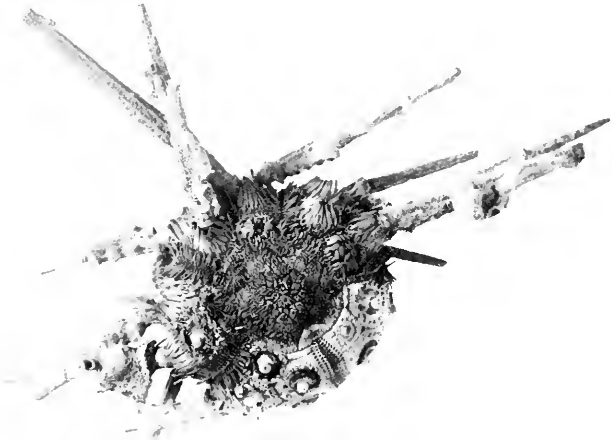

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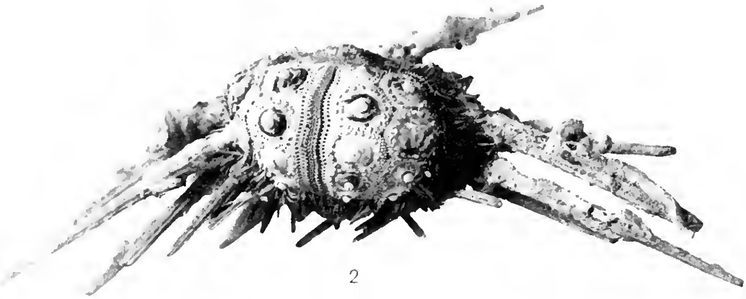

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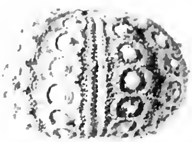

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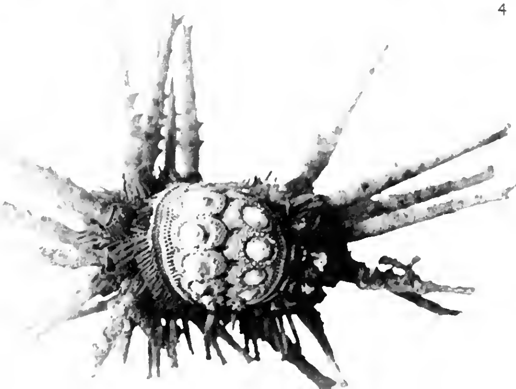

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PLATE 11.

Goniocidaris tubaria (Lamarck). Nat. size.

1. Abactinal view of partly cleaned, large specimen with short, stout spines.
2. Side view of same.

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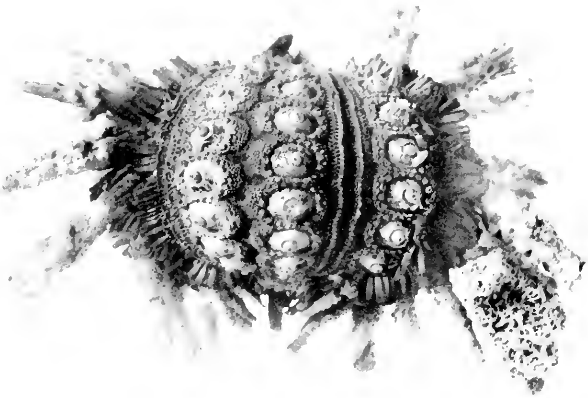

2

Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. LI. No. 8.

NOTICE OF SOME CRINOIDS IN THE COLLECTION OF THE MUSEUM OF COMPARATIVE ZOÖLOGY.

By Austin Hobart Clark.

With Two Plates.

CAMBRIDGE, MASS., U. S. A.:

PRINTED FOR THE MUSEUM.

January, 1908.

No. 8. — *Notice of some Crinoids in the collection of the Museum of Comparative Zoölogy.* By Austin Hobart Clark.

Two species of Crinoids were met with during the cruise of the "Albatross" in the eastern Pacific, one near the Central American coast, and the other approximately midway between the Marquesas Islands and Central America. The former, an unstalked form belonging to Heliometra, is represented by four specimens from three stations; the latter, a species of Bathycrinus, is represented by a single specimen without arms. The Bathycrinus, however, is a species of considerable interest, for not only does it greatly extend the range of the genus, which was hitherto known in the Pacific only from Kamchatka and southern Japan, but it presents a most extraordinary superficial resemblance to Rhizocrinus in certain of the characters of the stem and basals; so close, in fact, that the specimen was first recorded (Mem. Mus. Comp. Zoöl, 1906, **33**, p. 49) under that generic name, and a close examination under a microscope is necessary to reveal its true affinities.

Of the new species here described, *Heliometra juvenalis* calls for special mention. While undoubtedly closely allied to *H. eschrichtii*, it is remarkable in having prominent basals, cirri with less than twenty segments, and very short and stout lower pinnules, which are, in fact, much the shortest on the arms. The enlarged ovaries, however, containing ova, show that the specimens are adult, although the structure is that of very young specimens of other species of the genus. While no positive statement can be made on only two specimens, this seems to be a case of arrested development at a very early stage. Whether it is a permanent character or not must be left for future investigation; nothing similar is recorded, nor have I met with a similar case in my studies on the group.

STALKED CRINOIDS.

Bathycrinus equatorialis, sp. nov.

Radials and arms lacking.

Basals closely united into a smooth ring, slightly wider above than below, about as high as its greatest diameter; the sides of the ring are markedly convex, a character not known in any other species of Bathycrinus.

Stem 287 mm. long with ninety-two columnars; the five columnars immediately following the basal ring are very thin and discoidal, the sixth thicker, the seventh about twice the height of the sixth; the following segments increase in length, the sixty-fourth being 4.25 mm. long and 1 mm. in diameter, and the ninety-second 4.90 mm. long by 1.75 mm. in greatest diameter. The columnars differ from those of all known species of Bathycrinus in being practically cylindrical until after the eightieth, when the articulations begin to be very slightly enlarged; but they are never markedly "dice-box shaped," as in the other species. In general the stem bears a striking similarity to the stems of Rhizocrinus, the more so as the thin discoidal segments at the summit are closely united so as to appear, on superficial examination, as a single piece, and I had some difficulty at first in deciding to which genus it belonged. The basal ring is large for Bathycrinus, but shows no sutures whatever, even under strong magnification, nor is there the slightest evidence of incorporated radials. The small number of discoidal segments at the summit of the stem also suggests Rhizocrinus, but in that genus there are never more than two which are broader than long, and usually only one; the topmost columnar in Rhizocrinus, moreover, is always considerably longer than are the very thin proximal columnars of Bathycrinus. Examination of the surface ornamentation of the basals and columnars shows the deep and confluent pitting peculiar to Bathycrinus, and not the fine, shallow, scattered indentations of Rhizocrinus.

As an item of interest it may be mentioned that the seventeenth, fifty-fourth, and fifty-fifth columnars have the axes of both faces in the same plane; the axes are normally at right angles to each other, although occasionally the angle of divergence is considerably less than 90°.

The rapid enlargement of the proximal columnars, together with their segregation into what appears superficially to be a single segment, and the cylindrical form of the majority suggest an interesting possibility in regard to the original figure of *Bathycrinus aldrichianus.* Of this figure Dr. Carpenter says: "The numerous thin joints immediately beneath the cup, which are so characteristic of the genus, are not properly represented in the woodcut, and the joints just below where these ought to be are considerably longer than one would expect to find so near the cup. It may be assumed that Mr. Wild's drawing was photographic in its accuracy, so far as he could make out the structure of the small specimen; but errors may have crept in during its reproduction on wood, and the cut was published during Sir Wyville's absence from England, so that he had no opportunity of revising it. Under these circumstances it appeared preferable to say nothing about the stem in the specific diagnosis given above rather than to attempt to describe it from a probably incorrect woodcut." While in *Bathycrinus australis*, *B. carpenterii*, and *B. pacificus* from twenty to twenty-five or even more of the proximal columnars are short and discoidal, in *B. gracilis* and *B. complanatus* the number is much reduced, being only about half as many or even less; in *B. equatorialis* only the first five are short enough to be comparable to the proximal segments in the other species, and from then on the length increases rapidly.

In *B. aldrichianus* the stem is represented as having only a single segment wider than high. Judging from *B. equatorialis*, this segment might easily have been three or four coalesced columnars appearing as a single one, and that following might have been in a similar condition. Even if this were not so, the stem structure of *B. equatorialis* throws a new light on the specific variation in Bathycrinus, and suggests strongly that the stem of *B. aldrichianus* as figured is in all essentials correct. At the time the species was dredged by the "Challenger," the only small stalked crinoids on board were five specimens of Rhizocrinus; as all of the five had the characteristic basals still attached to the stems, confusion with them is out of the question. In the same haul with *B. aldrichianus*, it is recorded that Hyocrinus stems were secured; but the stem as figured is certainly not that of a Hyocrinus. Sixteen days later Rhizocrinus was dredged again; but in this case also the basals were *in situ*. Four months later *Bathycrinus australis* and Hyocrinus were dredged; but the stem cannot be that of either of these. It was not until the last of February three years later that any more small stalked crinoids were found, too late for their stems to have become incorporated in the figure.

Type Cat. 22,664, U. S. National Museum, from "Albatross" Station No. 4742, 0° 3.4′ north latitude, 117° 15.8′ west longitude, 2320 fathoms, taken February 15, 1905.

Bathycrinus caribbeus, sp. nov

Radials and arms lacking.

Basals closely united into a smooth ring, slightly wider above than below, longer than wide, the sides perfectly straight.

Stem 85 mm. long with about one hundred segments, the proximal seven short and discoidal, then rapidly becoming longer, reaching a length of 1.3 mm. with a width of 0.4 mm. in the middle of the stem, the last segment being 2.8 mm. long by 1.2 mm. in diameter at its much expanded end. Above the middle of the stem the columnars are cylindrical; distally the articulations become more and more prominent and are greatly expanded on the last two segments.

While it is possible that the elongated basals and small number of short discoidal joints in this specimen are indications of immaturity, the completely anchylosed condition of the basals and the apparently full complement of columnars seem to show that this is not the case; and that the latter may be characteristic of much larger specimens we have just seen in the case of *B. equatorialis*.

Bathycrinus caribbeus forms an interesting addition to the crinoid fauna of the Caribbean Sea, the more so since the depth at which it was found is considerably less than the lowest previous record for the genus (*B. carpenterii* 743 fathoms), while the bottom temperature (40° F.) is remarkably high.

Type Cat. 22,665, U. S. National Museum, from "Albatross" station No. 2751, 16° 54′ 00″ north latitude, 63° 12′ 00″ west longitude, 687 fathoms; blue Globigerina ooze ; bottom temperature, 40° F.

The discovery of four species of Bathycrinus since the publication of the

"Challenger" report makes a key to the species of the genus very desirable, especially since Dr. Carpenter in his key only included the three species discovered by the "Challenger" and the "Porcupine," omitting the interesting form dredged by the "Vøringen." In the preparation of the following key I have examined specimens of all the species given, with the exception of *B. aldrichianus*. There are two additional species as yet undescribed, one dredged by the "Valdivia" off Enderby Land, and the other from the Atlantic coast of the United States.

Key to the species of Bathycrinus.

A. Basal ring squarish, or wider than high.

- *a.* basal ring with straight or concave sides; columnars markedly "dice-box shaped," the articulations prominent; 10–25 short discoidal columnars at summit of stem.
  - *b.* arms perfectly smooth, brachials not overlapping.
    - *c.* costals and brachials low and rounded, non-carinate.
      - *d.* first brachials as long as or longer than wide; columnars short, 25 or more at summit of stem wider than high. (Northern and northeastern Atlantic). . . . . *B. carpenterii* (Danielssen and Koren).
      - *dd.* first brachials wider than long; columnars long, 15 or less at summit of stem wider than high. (Northwestern Pacific). . . . . *B. complanatus* A. H. Clark.
    - *cc.* costals distinctly carinate; brachials high, compressed, and carinate. (Near the Crozet Islands). *B. australis* A. H. Clark.
  - *bb.* brachials with raised and prominent distal edges, imparting a serrate appearance to the arms.
    - *c.* costals with a strong, rounded, median keel.
      - *d.* lower part of radial funnel much constricted. (Equatorial Atlantic). . . . . . *B. aldrichianus* Wyville Thomson.
      - *dd.* radial funnel slopes evenly downward from the upper to the lower edge. (Coasts of southern Europe). . . . . *B. gracilis* Wyville Thomson.
    - *cc.* costals with no trace of a median keel. (Off southern Japan). *B. pacificus* A. H. Clark.
- *aa.* basal ring with markedly convex sides; columnars cylindrical; five short discoidal columnars at summit of stem. (Equatorial Pacific). . . . . *B. equatorialis*, sp. nov

AA. Basal ring markedly longer than wide. (Caribbean Sea). *B. caribbeus*, sp. nov.

The following table gives the bathymetrical, thermal, and geographical range of each species of Bathycrinus, and of the genus as a whole, as now known; but the data given will doubtless be greatly modified by future discoveries, as but one species, *B. carpenterii*, can be considered to be even approximately understood; it is probable that the geographical range, even of this species, is much greater than that given, and there may be a corresponding lack of information in regard to the limits of the thermal and bathymetrical altitudes inhabited by it.

	Minimum Depth (Fathoms).	Maximum Depth (Fathoms).	Mean.*	Minimum Temperature (Fahrenheit).	Maximum Temperature (Fahrenheit).	Mean.*	Geographical Distribution.
Bathycrinus	**687**	**2535**	**1581**	**30.9°**	**40.0°**	**36.3°**	Probably cosmopolitan, but bounded by narrow thermal and bathymetrical limits.
B. carpenterii	743	1539	1116	30.9	34.8	32.8	Between Scandinavia and Iceland and northward.
B. gracilis	1093	2435	1764	36.5	36.5	36.5	Eastern Atlantic, from Finisterre south to about the Canary Islands (47° 38′ N. to about 30° N.).
B. aldrichianus	1850	1850	1850	36.6	36.6	36.6	Mid-Atlantic, east of St. Paul's Rocks (1° 47′ N. 24° 26′ W.).
B. caribbeus	687	687	687	40.0	40.0	40.0	Caribbean Sea.
B. australis	1375	1600	1487	34.2	36.6	35.4	Near the Crozet Islands, SW. of the Indian Ocean.
B. complanatus	1567	1567	1567	—	—	—	About 40 miles SSW. ½ W. of Copper Island, Commander group.
B. pacificus	905	905	905	36.6°	36.6°	36.6°	Off southern Japan.
B. equatorialis	2320	2320	2320	—	—	—	Between the Marquesas Islands and Central America (0° 3.4′ N. 117° 15.8′ W.).
B. sp.	2535	2535	2535	—	—	—	Off Enderby Land (about 66° S. 50° E.).

* Computed from all the published records.

UNSTALKED CRINOIDS.

Heliometra rhomboidea (P. H. Carpenter.)

This species was met with during the "Albatross" Eastern Pacific Expedition at three stations near the Central American coast; in all, four specimens were secured, a calyx without arms or cirri (Station No. 4622), an immature specimen and fragments of the arms of an adult (Station No. 4621), and a nearly perfect specimen, but with only three cirri remaining (Station No. 4630).

The specimen from Station No. 4630 expands 300 mm. The three remaining cirri have fifty-four, fifty-two, and forty-eight segments respectively. The first pinnule is 18 mm. long, with fifty-five segments, the second 22 mm. long, with fifty-three, and the third 17 mm. long, with thirty-one. The second pinnule is rather stouter than the first, the segments proportionately slightly longer; the third pinnule has the segments considerably elongated; the two following pinnules are about the length of the third, but have twenty-five to thirty segments, of which the terminal five or six are short, the others elongated. In the ten arms syzygia occur in all cases in the third brachials, nine times in the eighth (once in the ninth), once in the twelfth, twice in the thirteenth, five times in the fourteenth, and once in the fifteenth (the tenth arm is missing). Distally syzygia occur forty times at intervals of three brachials, eight times at intervals of four, and six times at intervals of two.

It will be seen that this specimen is almost identical with the one described by Dr. Hartlaub from the bay of Panama. I quite agree with him that it must be referred to *H. rhomboidea*, in spite of the fact that the species is not known between Panama and the Straits of Magellan. It is quite distinct from any of the numerous forms found along the shores of the north Pacific which were unknown at the time Dr. Hartlaub wrote.

The detached arms from Station No. 4621 are somewhat different from those of the specimen just noticed. The brachials are quadrate, all longer than wide, becoming elongate distally and overlapping, the distal border finely serrate; a close comparison shows that the brachials overlap rather more than do those of the other specimen, and the arms are therefore more rough, while the two proximal pinnule segments are proportionately somewhat larger (the first shorter and more oblong) and more expanded laterally, the second being more distinctly trapezoidal. The distal intersyzygial interval is decidedly more variable, being in four cases of two brachials, eight cases of three, thirteen of four, seven of five, six of six, four of seven, one of eight, and one of nine. These differences, however, are of minor systematic importance in this species, and, in fact, in many speices of Heliometra, although in others they may be of considerable value, and I have no hesitation in assigning this specimen, as well as the previous one, to *H. rhomboidea*. Station No. 4621 also yielded a small specimen having an expanse of 150 mm. The cirri have thirty-six segments, the third syzygy is usually in the fourteenth brachial (but once in the fifteenth), and the distal intersyzygial interval is three to five (usually three) segments. It will be seen that this

specimen, in regard to the disposition of the syzygia, most nearly agrees with the first.

The example from Station No. 4622 consisted merely of a calyx, without cirri, and with the arms lost after the third or eighth brachials; as nearly as can be determined, however, it is identical with the preceding.

In the more perfect specimen, the cirri had from forty-eight to fifty-four segments, while *H. rhomboidea* is given as having forty or less. This, however, is a matter of no importance, for the three remaining cirri of the specimen are of the type frequently seen on the extreme upper edge of the centro-dorsal in many species of Heliometra (in the type *H. eschrichtii*, for example) which are somewhat abnormal in being longer than usual, slender, with more than the normal number of segments; these must not be confused with the "long-mature" cirri of Dr. Carpenter, which arise just below them.

The following localities are added to the known distribution of *Heliometra rhomboidea*:

Station No. 4621. 6° 36′ north latitude, 81° 44′ west longitude, 36.4 miles from land; 581 fathoms.

Station No. 4622. 6° 31′ north latitude, 81° 44′ west longitude, 40.8 miles from land; 581 fathoms.

Station No. 4630. 6° 53′ north latitude, 81° 42′ 5″ west longitude, 556 fathoms; green sand, large Globigerinae; bottom temperature, 40.5° F.

Heliometra juvenalis, sp. nov.

Centro-dorsal hemispherical, bearing twenty to thirty cirri; these are 10–12 mm. long with fifteen to twenty segments, mostly somewhat longer than wide, but becoming squarish distally; there are no dorsal spines, but the distal border of the last five to ten segments is somewhat raised; basals plainly visible as interradial tubercles; radials about twice as wide as long; first costals rather shorter than the radials; axillaries pentagonal, about as long as wide; the costals are rounded and well separated laterally; ten arms 75 mm. long, the first brachial short and wedge shaped, the second larger and irregular, the four following oblong; from this point the brachials become obliquely quadrate, longer than wide, becoming more elongate distally; first pinnule 2 mm. long, with four or five squarish segments; second pinnule similar, but slightly longer; third pinnule longer still, with eight segments; the fourth pinnule is 4 mm. long, with about twelve segments; but the fifth is 6 mm. long, with fifteen segments, mostly rather longer than broad, of which the third, fourth, and fifth bear a large rounded genital gland; the fourteen following pinnules are similar, and bear also large genital glands, after which the pinnules become more slender, and do not develop genital glands; syzygia occur in the third, eighth, and twelfth brachials, and distally at intervals of three.

Color (in spirits) dull yellow; probably bright yellow in life.

Types Cat. 283, 284 M. C. Z., from off Cape Raper, Davis Strait; 60 fathoms; taken September 13, 1892, by Rev. A. M. Norman.

The two specimens upon which this species is based are among the most extraordinary unstalked crinoids I have ever seen; that they are adult is shown by the great enlargement of the genital glands, which contain ova; but all the other characters, the prominent basals, long radials, costals, and brachials, and rudimentary lower pinnules, and the few cirrus joints, are clearly juvenile, and in general the specimens appear to be much less developed than some of the very large *H. hondoensis*, which are less than half their size.

Psathyrometra, sp.

Some fragments of arms from "Albatross" Station No. 2818, 0° 29′ 00″ south latitude, 89° 54′ 30″ west longitude (Galapagos Islands), belong to a species of this genus, possibly *P. bigradata*, which has been found in the Galapagos group. The specimen was taken in 392 fathoms on a bottom of black and white sand, the bottom temperature being 43.9° F. The Galapagos specimen of *P. bigradata* was found in 385 fathoms, at a temperature of 43.2° F.

This is the first record for the arms of any species of the genus, outside of the Bering Sea and Sea of Japan, where fairly good specimens have been obtained. Dr. Hartlaub's examples all lacked the arms beyond the syzygy in the third brachial, and this is the condition in which species of this genus are usually recovered, as is the case with the closely allied Zenometra of the Caribbean Sea.

Antedon serrata, sp. nov.

Centro-dorsal low-hemispherical, bearing about thirty cirri; these are 7 mm. or 8 mm. long, and consist of eleven to fourteen segments, the first two short, the others rather longer than wide; the proximal half are more or less "dice-box" shaped; opposing spine minute; radials just visible as small interradial triangles; first costals very short; axillaries triangular, about twice as wide as high; ten arms 45 mm. long; first two brachials wedge shaped, the longer side out; third brachial wedge shaped, the longer side in; next three brachials oblong, then becoming quadrate, at first short, but after the eleventh about as long as wide, and elongate after the middle of the arm; syzygia occur in the third, eighth, and twelfth brachials, and distally at intervals of two; first pinnule 5 mm. long, composed of fifteen segments, the first very short, the second rather longer than broad, then becoming elongated; the ends of the segments are turned outward and produced dorsally, and armed with very fine spines; the five following pinnules are similar to the first, but considerably shorter, with the distal eversion of the pinnule segments more marked, the dorsal projection equal to from one half to nearly the whole length of the segment; the remaining pinnules become more slender, and the projection of the distal end of the pinnule segments gradually dies away.

Color (in spirits) brownish, the arms narrowly banded on about every third brachial with darker.

Type Cat. 254 M. C. Z., from Tokio Bay, Japan, 8–12 fathoms, Alan Owston collection, taken October 22, 1899.

The great amount of eversion and overlapping of the lower pinnule segments make this species one of the most readily distinguishable of the genus.

Antedon psyche, sp. nov.

Centro-dorsal low-hemispherical, bearing thirty to thirty-five cirri, the pole bare; cirri 7 mm. long, with fifteen or sixteen segments, all slightly longer than wide, remarkably uniform, the articulations somewhat expanded; there are no dorsal spines, but the opposing spine is prominent; radials visible as a low triangle in the interradial area; first costals low and wide, deeply incised by the axillary, and with a prominent latero-anterior tubercle; axillaries broader than long, produced posteriorly, where they rise into a slight rounded tubercle; the first costals and axillaries are in apposition laterally, but are not laterally flattened. Ten arms 55 mm. long, the first brachial wedge shaped (the shorter side in), the second irregular, and the third squarish; two following brachials roughly oblong, then quadrate, becoming triangular, longer than wide after the ninth, quadrate again at about the middle of the arm, and much elongate and "dice-box" shaped distally. First pinnule, 4 mm. long, with eight to ten segments, the first squarish, the following becoming progressively elongated; the pinnule tapers gradually from the base to the tip; second pinnule 7 mm. long, at the base about as stout as the first, but flagellate distally; it contains eleven segments, the first shorter than broad, the second longer than broad, the others elongated; the distal segments have the distal edges set with fine spines; the third pinnule resembles the second, but is shorter, and the fourth is shorter still, about the length of the first; the following pinnules become more slender, the distal pinnules being 7 mm. long, very slender, with fifteen to eighteen segments, the first two somewhat enlarged, the first broader than long, the second trapezoidal, and the others greatly elongated and slender.

Syzygia occur in the third, eighth, and twelfth brachials, and distally at intervals of one brachial.

Color (in spirits) light pinkish, the lower part of the arms, the calyx, and cirri, white.

Type Cat. 252 M. C. Z., Japan, probably in the vicinity of Tokio or Sagami bays. Alan Owston collection.

This species belongs to a small but interesting group of the genus Antedon, the species of which are characterized by small size, small number of cirrus segments, and by having the first pinnule never longer, and usually shorter and somewhat stiffer, than those following; the group comprises such species as *Antedon nana*, *A. briseis*, *A. minuta*, and *A. adrestine*, and occurs from Amboina and the Tonga islands northward to Japan. The comparatively large number of cirri on a hemispherical centro-dorsal, and the length of the second pinnule (which is much the longest) suffice to distinguish *A. psyche* from the other described species of this group.

Himerometra acuta, sp. nov.

Centro-dorsal discoidal or low-hemispherical, bearing about thirty-five marginal cirri; these are 20 mm. long with twenty segments, about half of which are rather longer than wide, the remainder squarish; the terminal segments are rather compressed laterally, and have a faint dorsal keel passing into the spine of the penultimate; radials just visible in the angles of the calyx; first costals short, oblong, free laterally, furnished with a rounded lateral projection; axillaries low pentagonal, nearly twice as broad as long; distichals two, articulated; the junctions of the costals, distichals, and lower brachials more or less tubercular, the costals and distichals having rounded lateral projections; twenty arms 85 mm. to 90 mm. long, the first six brachials oblong, the following obliquely quadrate (almost triangular), about half as long as wide, becoming less obliquely quadrate and finally oblong distally; first pinnule 4.5 mm. long, slender, weak, and tapering, with twelve or thirteen segments, the first three short, the remainder becoming progressively longer; second pinnule 10 mm. long, much stouter than the first, stiff and styliform, with fifteen segments, the first two wider than long, the remainder elongated; following pinnules shorter than the first, with about eight segments, gradually increasing in length distally.

Color (in formalin) yellow-brown, the skeleton dull yellow.

Types Cat. 288 M. C. Z. from Fiji, collected November 25, 1897; four specimens.

This species comes nearest to *Himerometra marginata* (P. H. Carpenter) from the Philippines, but the great enlargement of the second pinnule, which is styliform, stiff, and rigid, serves to distinguish it at a glance.

Himerometra heliaster, sp. nov.

Centro-dorsal low-hemispherical or thick discoidal, bearing thirty to thirty-five cirri in two or three more or less irregular marginal rows; cirri 20 mm. to 23 mm. long, with seventeen to twenty-three segments, mostly rather longer than broad, the distal without dorsal spines; opposing spine well developed; terminal claw short and curved; radials concealed; first costals narrow, oblong, about four times as wide as long; costal axillaries pentagonal, somewhat broader than long; costals rounded and widely free laterally, their junction slightly tubercular; distichals and palmars 2, the axillary resembling the costal axillary, the preceding segment like the first costal, but somewhat longer; twenty-five to thirty arms 125 mm. long, the first five or six brachials oblong and slightly tubercular, then becoming quadrate, nearly triangular at the seventh or eighth (much wider than long), then becoming gradually less and less obliquely quadrate, and practically oblong at the tips of the arms; syzygia occur in the third brachials, again between the sixteenth and twentieth, and distally at intervals of one to eleven (usually five or six); first pinnule 9 mm. long, slender and flagellate, with twenty-five segments, the first three squarish, then gradually becoming elongated (about twice as

long as wide, or even a little more, in the outer third of the pinnule), then short again on the terminal segments; second pinnule 15 mm. long, much stouter than the first, stiff, composed of fifteen segments, the first three squarish, then rapidly becoming elongated, reaching a maximum length (on the eleventh or twelfth) of somewhat over three times the width; third and following pinnules much shorter than the first (5 mm.), with twelve to fifteen segments, becoming gradually longer and more slender distally, where they are 9 mm. long. The first distichals, first palmars, and first brachials are united basally, but free distally; the axillaries and second and following brachials are widely free. In one arm of the type both the first and second brachials contain syzygies, and both bear pinnules.

Color (in spirits) grayish brown.

Type Cat. 290 M. C. Z. from Ebon, Marshall Islands, collected by Rev. B. G. Snow.

Himerometra persica sp. nov.

Centro-dorsal low-hemispherical, bearing about twenty-five cirri, a large area at the pole free; cirri 27 mm. long with thirty-five segments, mostly slightly longer than wide, becoming squarish distally, the last sixteen to eighteen bearing sharp dorsal spines; radials just visible; first costals trapezoidal, about three times as broad as long, axillaries pentagonal, about once and a half as broad as long, with a sharp anterior angle; costals rounded and widely free; distichals 4 (3 + 4) or 2; twenty to twenty-five arms 150 mm. long, the first eight brachials roughly oblong, then quadrate (much broader than long), becoming oblong toward the ends of the arms; a syzygy in the third brachial, another at about the seventeenth, and others distally at intervals of five to twelve (usually about seven); distichal pinnule 13 mm. long with thirty-six segments, all somewhat longer than wide, but not much so; the pinnule is very slender and flagellate, the first four segments being the broadest, and being slightly carinate; first brachial pinnule similar, but longer (16 mm.) and stouter basally, the five or six proximal segments sharply carinate, the pinnule then tapering gradually to the long delicate flagellate tip; the next pinnule is the same as that on the second brachial, and of the same length; the next few pinnules decrease rapidly in length, then increase somewhat distally, but do not become very long; the carination of the basal pinnule segments becomes less and less marked, and is not noticeable after the sixth; it is at its maximum on the pinnules of the second and fourth brachials.

Color (in spirits) dull brown, the skeleton somewhat lighter.

Types Cat. 291 M. C. Z. from the Persian Gulf, collected by F. W. Townsend.

This species is not very nearly related to any of the other species of Himerometra; according to the key given by Hartlaub for the "Savignyi Group" it would fall with *H. crassipinna;* but the slender and flagellate lower pinnules serve at once to distinguish it.

Note on six-rayed specimens of Tropiometra carinata (Lam.).

Six-rayed individuals of recent free crinoids have hitherto been regarded as quite rare. Although tetraradiate examples are not uncommon, I can find but a single record of a specimen with more than five radials. It was therefore with considerable surprise that I found among about three hundred and forty specimens of *Tropiometra carinata* no less than seventeen. It is interesting that all of the six-rayed specimens came from Rio Janeiro, all of the sixty or more from Zanzibar and Mauritius being normal. This gives us for the Brazilian specimens 6 % of six-rayed individuals.

These six-rayed specimens are all but one of comparatively small size, the diameter being between 100 mm. and 120 mm., the exception having an expanse of 190 mm.; this last is the only one sexually mature. Normal specimens of this species average from 230 mm. to 270 mm. in diameter, the size of those from Rio, Zanzibar, and the south Pacific being practically the same.

An examination of the disks of twelve of the specimens shows that in three cases it is quite impossible to determine which is the extra ray, as there are six ambulacra converging on the disk, all precisely alike; an examination of the rays themselves also furnishes no clue; one specimen has the interpolated ray between the two on the left side, one has it behind the right posterior, while seven have the extra ray inserted behind the left posterior.

Dr. Carpenter, in his monograph on the "Comatulae" collected by the "Challenger," mentions a small dry six-rayed "Antedon" in the British Museum collection. Suspecting from my examination of these specimens that it was probably an example of the same species, and also from Brazil, I wrote to Professor Bell of the British Museum for information concerning it. He very kindly replied that it was, as I had surmised, *Tropiometra carinata*, but there was no record of the locality whence it had come.

In the recent stalked crinoids it is interesting to note that *Rhizocrinus lofotensis* alone is known with more than five rays, and, as in *Tropiometra carinata*, this variation is confined to a single locality, the coast of Norway.

Among the fossil crinoids six-rayed individuals appear to be extremely rare, the figure by Rosinus (De stellis marinis quondam nunc fossilibus, p. 24, no. 3, pl. 1, fig. 3, 1719) of a six-rayed *Encrinus liliiformis* being the only record I know of this condition.

The genera used for the free crinoids in this paper are those recently proposed in a preliminary paper on a revision of the family Antedonidae (*sensu* A. H. Clark, 1907), in which that family is restricted so as to be equivalent to the genus Antedon, as understood by Dr. P. H. Carpenter. The old genus Antedon is broken up into a number of well-marked homogeneous genera, whereby the interrelations of the various species are much better shown than by the old method of uniting some three hundred or more widely varying specific types under one generic name. The following key shows the relations of these genera to each other from the point of view of differential characters. There are, in addition

to those given, two other types which should be raised to generic rank, but, as they are both West Indian and do not occur in the territory where the free crinoids considered here are found, it has seemed desirable to leave them for a report upon West Indian species.

Key to the genera of Antedonidae.

A. Pinnule ambulacra plated.

a. pinnules stout and prismatic, stiff, and closely set; radials and costals, and lower brachials, strongly flattened laterally (*i. e.* "wall-sided").

b. first pinnule similar to, but shorter than, those following; cirri very long, with more than 80 segments; the distal pinnules extend for several millimeters beyond the terminal brachials, which are abruptly recurved.

c. centro-dorsal long-conical or columnar, the cirri in 5 double vertical rows; cirri stout; 10–20 arms. . . . .
Asterometra (*Antedon macropoda* A. H. CLARK).

cc. centro-dorsal thick-discoidal or columnar, the cirri without definite arrangement, or in 15 more or less defined vertical rows; cirri slender; 10–30 arms . . . .
Ptilometra (*Comatula macronema* J. MÜLLER).

bb. first pinnule longer than those following; the distal pinnules short, not extending beyond the terminal brachials, which are not incurved.

c. first pinnule markedly larger, stouter, and longer than those following, composed of comparatively few large, stout segments; cirri elongate, slender, always spiny, with more than 25 segments; genital pinnules not differentiated; 10–30 arms . . .
Thalassometra (*Antedon villosa* A. H. CLARK).

cc. first pinnule longer, but smaller and more slender than those following, with much more numerous and shorter joints; cirri short, stout, and smooth, with less than 30 segments; genital pinnules always more or less expanded; 10–50 arms . . . .
Charitometra (*Antedon incisa* P. H. CARPENTER).

aa. pinnules rounded-carinate, the genital pinnules much expanded; costals and lower branchials laterally compressed, with concave sides, the former with broad, thin, flange-like latero-posterior borders; cirri short, stout, and smooth; 10 arms . . . .
Poecilometra (*Antedon acoela* P. H. CARPENTER).

aaa. pinnules cylindrical, stiff and spine-like, well separated, the first small, short, and weak, with squarish joints; proximal segment of lower pinnules (especially the first) enormously expanded; cirri spiny; 10–50 arms . . . . **Calometra** (*Antedon callista* A. H. CLARK).

aaaa. proximal pinnules slender, elongate, cylindrical, stiff, with much elongated segments, the first shorter than the following; distal pinnules strongly prismatic; costals and lower brachials rounded, free laterally; 20–30 arms . . . .
Stylometra (*Antedon spinifera* P. H. CARPENTER).

AA. Pinnule ambulacra not plated.

a. a pinnule on the third (epizygal) brachial.

b. costals united by syzygy; disk always more or less plated . .
Zygometra (*Antedon microdiscus* BELL).

bb. costals united by bifascial articulation; disk naked, or with small, scattered, calcareous granules.

c. lower pinnules stout and prismatic, subequal in length; costals and lower brachials in close apposition, with sharply flattened sides.

d. one of the lower pinnules somewhat enlarged; first two brachials not enlarged; first pinnule as large as or larger than the second or third; distal pinnules do not extend beyond tip of arm; brachials long, triangular, or quadrate; 10 arms . . . .
Nanometra (*Antedon minor* A. H. CLARK).

dd. lower pinnules about equal in size, but the first somewhat shorter than those following; distal pinnules extend beyond tip of arm; brachials very short, oblong, or short-quadrate, the first two disproportionately large; 10 arms . . . .
Tropiometra (*Comatula carinata* LAMARCK).

cc. one or more of the lower pinnules elongated, slender, and flagellate, cylindrical, or flattened.

d. the greatly elongated and flagellate lower pinnules are composed of very numerous short and broad segments, and are more or less serrate toward the tip; costals always well-separated and rounded; centro-dorsal hemispherical, with very numerous cirri, which are long with numerous segments, long proximally, shorter distally, where they are sharply carinate or bear low spines; terminal claw curved, moderate in length, or short, always with an opposing spine; middle and distal brachials triangular or quadrate; 10 arms . . . . .
Heliometra (*Alecto eschrichtii* J. MÜLLER).

dd. the first of the greatly elongated and flagellate lower pinnules is composed of very numerous short and broad segments; but the others are composed of greatly elongated smooth segments; rays rounded, well-separated; centro-dorsal discoidal, bearing very numerous cirri, which are long, with greatly elongated smooth segments; terminal claw long and nearly straight, with no opposing spine; middle and distal brachials oblong; 10 arms . . . .
Thysanometra (*Antedon tenelloides* A. H. CLARK).

ddd. all of the lower pinnules have elongated segments.

e. first segment of the elongated lower pinnules always short; costals and lower brachials usually rounded and free laterally, occasionally

flattened against each other; centro-dorsal hemispherical or discoidal, the cirri without definite arrangement; cirrus segments fairly uniform throughout, one or more always markedly "dice-box shaped;" 10 arms . . . .

Antedon de Fréminville, 1811, (*Asterias bifida* PENNANT).

ee. all the pinnules, especially the lower, greatly elongated, the latter composed of greatly elongated segments of which the first, like those following, is greatly elongated; centro-dorsal conical or columnar, with 5 broad inter-radial areas or ridges dividing it into five radial areas, each with definite vertical rows of cirrus sockets; 10 arms.

f. costals and lower brachials smooth, well separated, and rounded, cirri smooth, with all the segments elongated, arranged in 3, 4, or 5 vertical rows in each radial area.

Psathyrometra (*Antedon fragilis* A. H. CLARK).

ff. costals and lower brachials in close apposition and strongly "wall-sided"; cirri with much elongated segments proximally, very short and spiny segments distally, arranged in two vertical rows in each radial area . . . .

Zenometra (*Antedon columnaris* P. H. CARPENTER).

ccc. lower pinnules cylindrical, one or more very stout, styliform, and more or less elongated.

d. cirri with 50–70 short segments, bearing stout spines distally; first pinnule only enlarged, greatly elongated; following pinnules very short, in abrupt contrast; costals and lower brachials with straight sides, the former rounded and widely separated; brachials triangular or quadrate, rather long; 40–60 arms . . .

Pontiometra (*Antedon andersoni* P. H. CARPENTER).

dd. cirri with 15–40 subequal short segments; the enlarged lower pinnules followed by pinnules of intermediate character.

e. cirri irregularly placed on a discoidal centrodorsal; costals and lower brachials with convex sides, giving them a characteristic swollen appearance; brachials short, mostly oblong or short-quadrate; 10–50 arms . . . .

Himerometra (*Antedon crassipinna* HARTLAUB).

ee. cirri in ten vertical rows on a conical centrodorsal; costals and lower brachials with straight sides; brachials long; 10–15 arms.

Adelometra (*Antedon angustiradia* P. H. CARPENTER).

aa. no pinnule on the third (epizygal) brachial.

b. centro-dorsal discoidal, the few short and stout cirri in two or three irregular marginal rows; radials and lower brachials not tubercular; 10–30 arms . . . .

Cyllometra (*Antedon manca* P. H. CARPENTER).

bb. centro-dorsal conical, the numerous elongate and slender cirri in more or less definite vertical rows; costals and lower brachials strongly tubercular; 10 arms . . . .

Perometra (*Antedon diomedeae* A. H. CLARK).

PLATE 1.

Fig. 1. *Bathycrinus equatorialis.* Type.
Fig. 2. *Antedon psyche.* Detached arm.
Fig. 3. *Antedon psyche.* Type.
Fig. 4. *Antedon serrata.* Type.
Fig. 5. *Heliometra juvenalis.* Type.

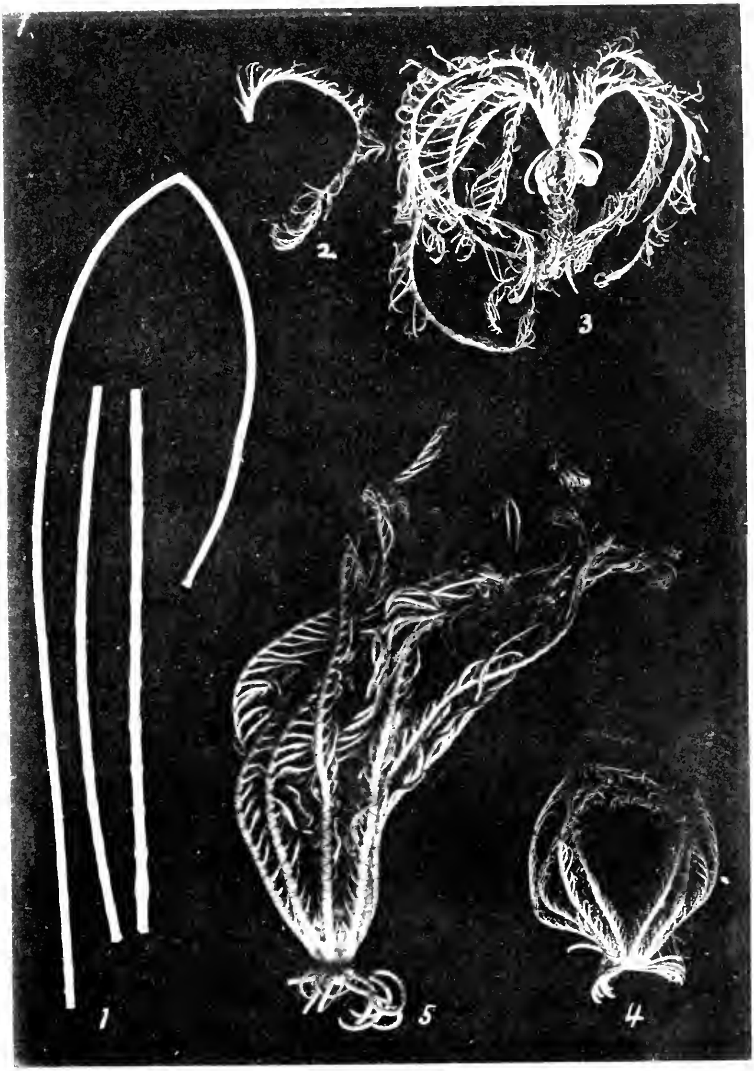
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PLATE 2.

Tropiometra carinata.

Specimens showing six rays.

Fig. 2, specimen with six equal ambulacra. Fig. 4, specimen with five primary ambulacra, that running to the right posterior arm dividing, one half going to a ray interpolated between the right and left posterior rays.

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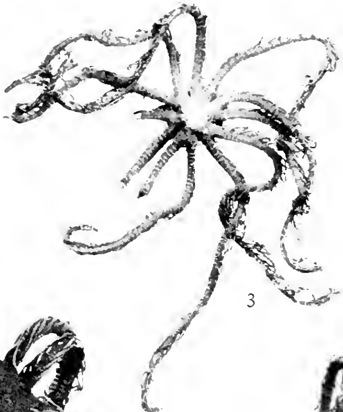

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Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. LI. No. 9.

NEW PLAGIOSTOMIA AND CHISMOPNEA.

By Samuel Garman.

CAMBRIDGE, MASS., U.S.A.:

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February, 1908.

No. 9. — *New Plagiostomia and Chismopnea.* By Samuel Garman.

Plagiostomia.

In the Myliobatidae there are four well-marked genera. Three of these have been established in some manner ever since the time of Cuvier. The fourth, Aetomylaeus, species of which have been recognized quite as long, has been lost in one of the others, hidden by resemblances. Outwardly its species are so like those of Myliobatis that they have readily passed as congeneric. It was only upon the disclosure of internal differences of the structure that the value of certain external peculiarities was given proper consideration. The absence of a serrated spine behind the dorsal fin, if not the result of accident, for one item, has been looked upon as questionably sufficient for specific distinction. On dissection of some of the species, however, this feature is found to be associated with a division of each pectoral at the side of the head, that is, with absence of pectoral rays connecting the cephalic portions with the main sections of the pectoral fins, a characteristic of Aëtobatus and not of Myliobatis in which the species have been located heretofore. We may note slight differences in the appearance of the pectorals opposite the angles of the mouth after discovery of the lack of pectoral rays in these positions, but the import of these features has been overshadowed by the fact that in the species under notice they are associated with a dentition practically the same as that of Myliobatis. Further comparisons assure us that in these species we are dealing with a genus distinct from Myliobatis and considerably more specialized, as is evident from the division of the pectorals and the loss of the serrated dorsal spine. In brief summation, the new genus agrees with Myliobatis in dentition and in nasal valves, while it differs in the divided pectorals and in the lack of a dorsal spine; and it agrees with Aëtobatus in the pectoral divisions, while differing in regard to dentition, nasal valves, and absence of the spine. These peculiarities, with others of less value perhaps, suffice to fix the place of the new genus, Aetomylaeus, as intermediate between Myliobatis and Aëtobatus. How the divergences and the accompanying af-

finities affect the classification may be more clearly seen in the following synopsis:

Pectoral fins continuous at the sides of the head;
  a serrated spine behind the dorsal fin;
    nasal valves confluent, broadly free behind the isthmus;
      teeth of each jaw in a broad median and in narrow lateral series *Myliobatis.*
Pectorals not continuous, the two cephalic parts forming one lobe;
  no serrated spine behind the dorsal fin;
    nasal valves in a quadrangular flap, free behind the isthmus;
      teeth of each jaw in a broad median and in narrow lateral series *Aetomylaeus.*
  A serrated spine behind the dorsal;
    nasal valves in two pointed lobes, not free behind the isthmus;
      teeth of each jaw in a broad single row . . . . *Aëtobatus.*
Pectorals not continuous, cephalic portions in two lobes;
  a serrated spine behind the dorsal fin;
    nasal valves confluent, broadly free behind the isthmus;
      teeth of each jaw in seven or more rows, median more often
        broader . . . . *Rhinoptera.*

Aetomylaeus, gen. nov.

The body and fins of this genus are like those of Myliobatis and of Aëtobatus. It is distinguished from both by absence of a serrated dorsal spine on the tail, from the first by absence of pectoral rays connecting the cephalic with the main lateral portions of the fin, and from the second by the dental laminae, each of which consists of a broad median series at each side of which there are three narrow rows, as in Myliobatis. The mesopterygia are fused with the shoulder girdle, as in Aëtobatus.

This genus partakes of the characters of both the genera mentioned; but by the grouping of those possessed in common, and by the possession of others peculiar to itself, it appears to be entitled to recognition as distinct from either. The type species is that figured by Gray, 1834, in the Illustrations of Indian Zoölogy, **2**, Plate 101, under the name *Myliobatis maculatus*, and described by Müller and Henle in 1841. The species described by Müller and Henle as *Myliobatis milvus* has the same structure, and in all probability *Raia nichofii* of Bloch and Schneider, and *Myliobatis vespertilio* of Bleeker agree with maculatus in their anatomy and should be included. Provisionally the genus may be constituted as below.

No caudal spine; tail long, slender, whip like;
  origin of dorsal fin behind the ends of the bases of the ventrals;
    back armed with small tubercular spines in the middle;
      disk less than twice as wide as long;
        brown-edged ocelli on the hinder part of the disk . . . . . *maculatus.*

Origin of dorsal fin opposite the ends of the bases of the ventrals;
  back smooth;
    disk less than twice as wide as long;
      green brown-edged ocelli on hinder part of disk . . . . *milvus.*
    Disk twice as broad as long;
      blue cross-bands, about five, disappearing with age, no spots . *nichofii.*
Origin of dorsal fin backward from ends of bases of ventral fins·
  back smooth;
    disk less than twice as broad as long;
      brownish with networks of black lines, anteriorly in bands . *vespertilio.*

Rhinobatus rasus, sp. nov.

The snout of this species is pointed and elongate, more than three and a half times the width of the crown between the orbits. The rostral ridges are close together, parallel in most of their length, and show little or nothing of a groove between them. The crown is broad and has little convexity. The eyes are small and prominent. Each spiracle is as large as the eye and has two folds on the hind margin, the inner one of which is the smaller. In width the nostrils are about one-fourth of the snout. The anterior nasal valve is narrow and does not extend upon the internarial space. Mouth, in width more than one-third of the length of the snout, nearly straight. Entire upper surface covered with fine scales, which are larger near the vertebral column and on the top of the head. A row of larger tubercular scales on each rostral ridge; two stronger tubercles in front of each eye, one or more at the inner edge of each spiracle, a row of nineteen large tubercles from the back of the head to the first dorsal fin, and a pair, the outer one of which is smaller, on each shoulder. Lower surfaces entirely covered by fine shagreen. Of the fins the hinder angle on each dorsal is pointed and the hinder margins are concave; the caudal is narrow.

Brownish, whitish at each side of the rostrum, with a darker area opposite the shoulder girdle on the base of each pectoral fin, and with a clouded spot of darker below the end of the snout on an otherwise uniform whitish lower surface.

Type Cat. 235 M. C. Z., from Akkra, Gulf of Guinea.

This species is distinguished from the species *R. percellens* and *R. rhinobatos* by the pointed snout, the narrow nasal valve, the enlarged scales on the middle of the upper surfaces, and especially by the rostral ridges.

Rhinobatus acutus, sp. nov.

Rhinobatus acutus is readily distinguished from *R. rhinobatos* by its very long and more pointed snout, by its narrow nostrils, and by its wide internarial space, which last is one and one-third times the width of the nostrils; these features also separate this form from any other of the Indo-Asiatic species. Snout long, length little less than one-fourth of the total length, ending in a sharp point. Mouth nearly midway between the pelvis and the end of the snout, slightly arched, in width little less than one-third of the length of the snout. Rostral ridges slender, not widened at the end, confluent at about one-fifth of their length from their

bases, beyond which point to the extremity the ridges are hardly distinguishable. In either a transverse or a longitudinal section between the eyes the crown is convex. Spiracle as large as the eye, with two rudimentary folds on the hind margin of equal size and remote from one another. Nostrils comparatively small, in width about two-thirds of the internarial space and elliptical in shape, rather than short and broad and larger at one end than at the other, as is the case with *R. rhinobatos*, *R. thouini*, and allies; distance of the outer angle of one from that of the other less than half the length of the snout. Anterior nasal valve small, lateral extension from the free portion less than the length of the latter, not extended from the margin of the nostril. The anterior nasal valve is not continued to the inner angle of the nostril; it is not extended upon the internarial space; in fact it is carried very little of the distance from the free flap, or cirrus, toward the angle. Scales very small, keeled or sharp-pointed on the upper surfaces, those on the under surfaces more flattened. Compressed sharp tubercles appear in a row on each rostral ridge, increasing in size backward; three tubercles in front of each orbit, and a couple at the inner edge of each spiracle. About twenty larger tubercles occur between the back of the head and the first dorsal fin in a vertebral row; there is a pair of tubercles at each side of this row on the shoulder girdle, the inner one of each pair being the larger. A single tubercle stands at the origin of the second dorsal fin. Of the dorsal fins the second is somewhat larger than the first; both are convex on the front margin and concave on the hinder. The fin area of the caudal fin is small.

Color an olivaceous-brown or brownish olive on the back, darker toward the spinal column, dingy white at each side of the rostral cartilage and between the ridges at its base, whitish on the lower surfaces.

Type Cat. 807 M. C. Z., from Ceylon.

Raia kincaidii, sp. nov.

On the fins of *Raia kincaidii* the angles are so broadly rounded that the disk is best described as subround. The snout is of medium length; it is outlined in broad curves, and the tip has the appearance of an oblong or quadrangular slightly produced inset; the rostral cartilage is broad at the skull and tapers rapidly about half the way to the tip, where it ends in a sharp point. The eyes are of medium size; they are prominent, and the interorbital space is slightly convex. Mouth moderate, curved forward in the middle, as wide as the distance between the shoulder spines, which is a little less than half that of the mouth cleft from the tip of the snout. Teeth rather large, in thirty-three rows on the upper jaw and thirty-one on the lower, with flattened crowns from which there is a raised sharp cusp at the posterior margin. Gill clefts small, the greatest width not more than half the length of the eye. Tail as long as the disk, depressed and strong anteriorly, tapering gradually to slender, with a dermal fold on each side and with a finlet behind the second dorsal. Dorsal fins equal, separated by a space of the ocular width bearing one or more tubercles. Upper surface covered by small, sharp, closely set hooked scales: a row of twenty-nine larger tubercles —

compressed, hooked, striate-based, buttressed in front — above the vertebrae from the back of the head to the second dorsal fin; no larger tubercles around the eyes or the spiracles. Ventral fins broad, anterior portion of moderate length, notch of medium depth, containing four digits.

Color of the back uniform slaty or leaden-brown, with small spots of black. A white spot on each side of the tail at one-fourth of the distance from the base to the end of the second dorsal fin, and a faint spot of light color near the middle of the hinder half of each pectoral fin. Lower surface of disk white, smooth; lower side of tail darker along the middle.

Type Cat. 1261 M. C. Z., from Friday Harbor, Washington.

The name is given in honor of Dr. Trevor Kincaid, to whom we are indebted for knowledge of the species.

Chismopnea.

Chimaera barbouri, sp. nov.

As compared with other species of the genus the body of this one is moderately stout and the tail is somewhat less elongate. A feature that at once serves to distinguish this species is the shape and height of the second dorsal fin; as on *Chimaera mirabilis* of Collett, this fin is high anteriorly and posteriorly, and the outline is convex, while in the middle of its length there is a deep concavity where the height of the fin is less than half as much, the lowest portion being reached by a gradual descent from either end. The eye is large; it occupies nearly one-third of the length of the head. The snout is massive; its length is greater than that of the eye. The dental plates are thin and sharp on their outer edges. In each vomerine plate there are five enamel rods, as in *C. monstrosa*, but in *C. barbouri*, the inner one of the five, the longest and the strongest, stands at a little distance from the others. Each palatine plate has a pair of prominent longitudinal tritors on its side near the inner edge, and on each mandibular plate there is a single prominence not so elongate as those to which it is opposed on the roof of the mouth. These lateral tritors, being the results of wear on the sides of the enamel rods, only appear in older individuals, and of course are not present in the younger ones, which are provided with the marginal tritors on the edges of the plates, on the ends of the enamel rods, as was pointed out for other species of Chimaera in the article on the Chismopnea, 1904, Bull. M. C. Z., **41**, p. 258. In a measure the palatine and mandibular plates of the specimen before us resemble those of some Callorhynchi, as may be seen by comparing with figures 1–4 of Plate **6** of the mentioned article.

In the first dorsal fin the spine is triangular; it bears hooked spinules on the hinder angles. The dorsals appear to be widely separated, but they are united by a very low fold of membrane. The height of the first dorsal, from origin to apex, is much less than the entire length from the second dorsal to the origin of the first. The greatest length of the rays of the second dorsal approximates the length of the eye, which is about twice the length of the rays in the depth of the concavity of the fin. In height the supracaudal fin is somewhat less than

the second dorsal, and perhaps the rays are a trifle longer than those of the subcaudal, which fin extends much farther forward and backward than the supracaudal. A deep notch not quite reaching the inner edge of the fin separates the second dorsal from the supracaudal, and immediately behind this notch there is a portion of the supracaudal, in the individual under description, which rises in a sharp point followed again by a sharp notch not half the depth of the fin. It may be this point is a mere variation in this specimen. The caudal filament is of medium length; it is apparently complete. There is no separate anal fin. As in *C. affinis,* the pectoral does not reach the ventral; it is broader and less narrowed toward the end than in *C. monstrosa.*

Lateral Line System. — One respect in which this species differs from other Chimaerae is seen in the aural section of the lateral line system. On others the aural makes an angle backward in the middle and from this angle sends back a short line toward the dorsal spine; on the present specimen the line makes a curve across the aural region and has neither the angle nor the line extending backward. It is like that of the Callorhynchus figured in the article on the lateral system, Garman, 1888, Bull. M. C. Z., **17**, Plates **3** and **4**, and is unlike the aural of *Chimaera monstrosa*, as figured on Plate **2** of the same article, or of the other species of the genus. The lateral line on the flank starts from the junction of the occipital and the orbital in a short descending curve, behind which it rises to curve in the opposite direction, making a sigmoid from which it takes a nearly straight course backward to descend to the lower edge of the muscular bands of the tail below the anterior portion of the supracaudal fin. The jugular and the oral portions of the line are separated by a short space at their junction with the orbital. The oral makes a decided curve backward below the orbital above the angular, and another below it; in other Chimaeras the oral is more nearly straight. The outward curve in each cranial is farther forward than on *C. phantasma,* that is, farther from the aural junction, and the oral curves are more pronounced. The great curve, in front of the eye, in the suborbital, is more open than that of *C. phantasma,* more nearly resembling that of *C. mitsukurii;* it does not make so great a turn backward before passing forward to meet the rostral.

The back is dark brown or blackish, shading to light on the lower portions of the flanks, and is marked by white spots: a small spot of white in front of each eye, another behind each orbit, one on each shoulder below the base of the dorsal spine above the lateral line, a larger one below the hinder extremity of the first dorsal, one below the anterior portion of the second dorsal, and another below the lateral line above the base of each ventral fin. Anteriorly the white spots are about the size of the pupil; posteriorly they are larger. Slight cloudings in the brown on the lower parts of the sides may or may not be due to accidents in preservation.

Type Cat. 1281 M. C. Z., from Aomori, near Tsugaru Strait, Japan.

Named in honor of Mr. Thomas Barbour, through whose enthusiastic interest the opportunity of description was provided.

Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. LI. No. 10.

NEW PHYTOPHAGOUS HYMENOPTERA FROM THE TERTIARY OF FLORISSANT, COLORADO.

By Charles T. Brues.

CAMBRIDGE, MASS., U. S. A.:

PRINTED FOR THE MUSEUM.

March, 1908.

No. 10. — *New Phytophagous Hymenoptera from the Tertiary of Florissant, Colorado.* By CHARLES T. BRUES.

OVER a year ago I received from the Museum of Comparative Zoölogy the large collection of undetermined fossil phytophagous and parasitic Hymenoptera collected many years ago by Dr. S. H. Scudder in the Tertiary lake basin at Florissant, Colorado. Since then a large number of additional parasitica have been received from the same locality from Prof. T. D. A. Cockerell, who has been collecting there for the past two summers.

The present paper contains a consideration of the phytophagous forms belonging to the Tenthredinidae, Lydidae, and Siricidae. These are very much less numerous than the parasitic ones.

Three genera and twelve species are described as new, and reference has been made to the more definite records of occurrence of members of the group in the various Tertiary formations of Europe and North America, the only continents where they have been discovered.

A catalogue of the recorded species and genera is also included.

The figures are reproduced from drawings made with the aid of a camera lucida.

TENTHREDINIDAE.

Trichiosomites, gen. nov.

Radial cell of front wings long, not appendiculate; divided at its basal third by a transverse nervure. Submedian cell only a little longer than the median. Anal cell divided into cells connected by a petiole, much as in Pachyprotasis or Hemichroa. Basal vein and first recurrent nervure almost parallel, the second transverse cubitus and the second recurrent nervure interstitial.

The long marginal cell and interstitial second recurrent nervure remind one of Trichiosoma, as does also the oval abdomen. There are such important differences, however, that I feel compelled to erect a new genus for the reception of the single species, which I cannot place in any described genus. The long marginal cell is similar to that of Paremphytus.[1]

[1] Since this paper went to press Mr. S. A. Rohwer of the University of Colorado writes me that he has identified the same species in material from Florissant, which shows that the genus is closely related to Zarea Leach. The antennae are six-jointed.

Trichiosomites obliviosus, sp. nov.

Length 9 mm. Body broad and stout, the width of the abdomen being 3 mm. Color apparently black, with more or less brownish on the abdomen. Wings hyaline, the veins dark. Head rounded on the sides, its surface finely shagreened; mesonotum more coarsely so or finely punctulate. Scutellum smooth. Metanotum more or less rugose. All of the abdominal segments are of nearly equal length, the fifth widest, one and one-half times as wide as the first. Abdomen in outline regularly oval. Marginal cell in front wings very long and narrow, pointed, but not at all appendiculate, divided by a cross-vein at its basal third.

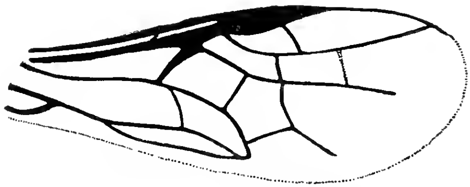

Fig. 1. — *Trichiosomites obliviosus* Brues. Fore-wing.

Humeral area divided by a cross-vein near the origin of the basal vein; submedian cell longer than the median by one-third the length of the transverse median nervure. Basal vein and first recurrent nervure almost parallel. First and second submarginal cells not separated, the second recurrent nervure interstitial with the second transverse cubitus. Anal cell as in Pachyprotasis, divided into two by the fusion of the anterior and posterior nervures; the petiole thus formed as long as the distance from the fusion to the transverse median nervure.

Type. — No. 2036, Mus. Comp. Zoöl., Florissant, Col. (No. 1381, S. H. Scudder Coll.).

Phenacoperga Cockerell.

The type species and only one so far made known is *P. coloradensis* Ckll., from Florissant. It was first described in the genus Perga (Cockerell, **:07**[a]), but later made the type of Phenacoperga by its author (**:08**).

Lophyrus Latreille.

Brischke (**'86**) records the occurrence of Lophyrus in Prussian amber, but the genus has not been found fossil elsewhere.

Hemichroa Stephens.

A single species, *H. eophila* Ckll., has been described from Florissant by Professor Cockerell (**:06**), who refers it to this genus without any doubt. There are no specimens in the collections which I have seen.

Dineura Dahlbom.

Cockerell (:06) has already recognized a species of this genus from Florissant to which he gives the name *Dineura saxorum*, and there is a second one in the present collection. The two may be separated as follows:

Transverse median nervure received much before the middle of the first discoidal cell; second recurrent nervure inserted a considerable distance before the tip of the second submarginal cell . . . . *saxorum* Ckll.

Transverse median nervure received just at or a trifle before the middle of the first discoidal cell; second recurrent nervure inserted at the extreme tip of the second submarginal cell . . . . *laminarum*, sp. nov.

Dineura laminarum, sp. nov.

Probably a female. Length 10 mm. Head and thorax very dark and abdomen pale, except at the tip, where it is brownish. Head rather small and narrow. Antennae black, very gradually attenuated toward the tip, reaching as far back as the base of the metanotum. The mesonotum is brown, with a narrow black border anteriorly, and shades into black behind. Scutellum black. Sides of the metanotum apparently pale like the abdomen. Legs, especially the posterior pair, distinctly preserved, apparently brown; tibiae and tarsi of the hind pair

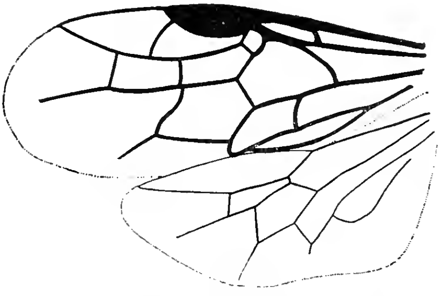

Fig. 2. — *Dineura laminarum* Brues. Wings.

darker above. Wings hyaline, the veins fuscous or piceous. Humeral cross-vein inserted a short distance before the origin of the basal vein; transverse median nervure inserted just before the middle of the first discoidal cell. Marginal cell long and pointed, its cross-vein distinct. First submarginal cell quadrate, the first transverse cubitus and the first section of the cubitus subequal, second section a trifle longer. Second recurrent nervure inserted at the apex of the second submarginal cell, being almost interstitial with the second transverse cubitus. Anal cell with a long petiole. Recurrent nervure in hind wing inserted three-fifths of the way from the base of the second submarginal cell.

Type. — No. 2037, Mus. Comp. Zoöl., Florissant, Col. (No. 4983, S. H. Scudder Coll.).

This species approaches the genus Mesoneura in the disposition of the recurrent nervures in both pairs of wings, the second being almost interstitial with the second transverse cubitus. This character apparently tends to vary, however, as the vein is more nearly interstitial in one wing than in the other.

It is a broad, stout species.

Pteronus prodigus, sp. nov.

Sex? Length about 7 mm., most of the head broken away. Color dark, varied with paler. The anterior part of the mesonotum and the prothorax are yellowish, while the scutellum and metathorax are darker. The mesonotum has an anterior triangular dark spot and dark lateral margins. Abdomen pale, banded on each segment with fuscous. The bands of the first and second segments reach only half-way across; the following grow wider to the sixth, and the seventh is again narrower. Wings hyaline, the venation as in Pteronus. Humeral field divided by a cross-vein opposite the base of the first discoidal cell. Marginal cell long and lanceolate, not divided. First submarginal cell small, obliquely rounded above, the first and second sections of the cubitus equal. Second sub-

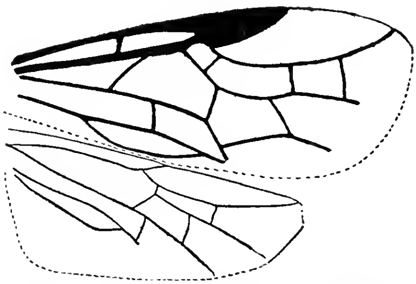

FIG. 3. — *Pteronus prodigus* Brues. Wings.

marginal cell very long, over three times as long as the second section of the cubitus, receiving the two recurrent nervures. Third submarginal cell distinctly longer than high, and higher at the tip than at the base. Anal cell petiolate, its petiole originating just basad to the lower end of the basal nervure. Hind wings with the first discoidal and first submarginal cell separate.

Type. — No. 2038, Mus. Comp. Zoöl., Florissant, Col. (No. 14,071, S. H. Scudder Coll.). It is in a fine state of preservation, showing both front and hind wings, but lacking a part of the head.

The venation in this species is exactly like that of recent species, and the color markings are disposed with a similar tendency to those of *P. ribesii* Scop. and *P. mendicus* Walsh, two common North American species of recent times.

Serres in his Géognosie ('29) has referred a fossil species from Aix to this genus, but it is very doubtfully a member of Pteronus, as the genus is at present restricted.

Scolioneura vexabilis, sp. nov.

Length 9 mm. Broad and stout, dark colored or black with paler markings. Abdomen ferruginous except at the base and apex. Dorsum of thorax indistinctly pale around the edges. Antennae preserved only near the base, black; the joints toward the base about five or six times as long as wide. Thorax as wide as long, and not quite so wide as the oval abdomen, which is twice as long as wide. Wings indistinctly infuscated towards the base, the veins brown. Anal cell lanceolate, petiolate, as wide at its broadest part as three-fourths of the length

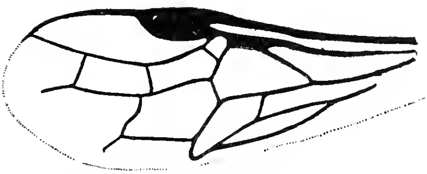

FIG. 4. — *Scolioneura vexabilis* Brues. Fore-wing.

of the transverse median nervure. Marginal cell long and narrow, pointed at apex; apparently not divided by a nervure. First submarginal cell small, more or less rounded at its base; second and third long, each receiving a recurrent nervure; basal vein and first recurrent nervure widely divergent behind.

Type. — No. 2039, Mus. Comp. Zoöl., Florissant, Col. (No. 1520, S. H. Scudder Coll.).

This species might perhaps be excluded from Scolioneura, as I cannot make out any cross-vein in the marginal cell. I can find no other suitable place, however, and think that it may best be left here. The hind wings are not well enough preserved to show their venation, but the front ones are in good condition, with the exception of a part of the apical portion.

Selandria Leach.

Brischke (**'86**) mentions the occurrence of a single specimen belonging to Selandria in Baltic amber. Curtis (**'29**) compares a form from the lower Oligocene at Aix with *Selandria fuliginosa*, but the latter is evidently the *Tenthredo fuliginosa* now placed in Tomostethus Konow.

Eriocampa Hartig.

Cockerell (**:06**) has described *Eriocampa wheeleri* from Florissant, and there is a second species to be added from the Scudder collection. The two may be separated as follows:

Second submarginal cell on the radius more than twice as long as the first submarginal on the cubital side; cross-vein in marginal cell strongly oblique; wings infuscated . . . . *scudderi*, sp. nov.

Second submarginal cell on the radial side no longer than the first submarginal on the cubital side. Wings hyaline . . . . *wheeleri* Ckll.

Eriocampa scudderi, sp. nov.

Length about 9 mm. Body seemingly wholly black, with infuscated wings. Nervures piceous. Hind legs, or at least the femora and tibiae, black. Marginal cell long and pointed, the cross-vein strongly oblique, inserted much nearer to the tip than to the base of the second submarginal cell. First submarginal cell small, narrowed at the tip, the first transverse cubitus being only two-thirds the length of the first section of the cubitus. Second submarginal cell long and narrow,

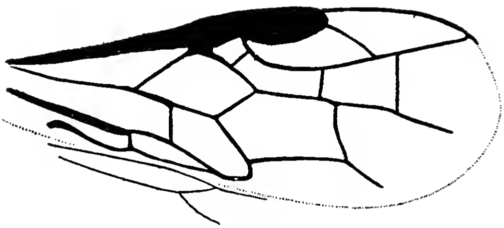

Fig. 5. — *Eriocampa scudderi* Brues. Fore-wing and a small portion of hind-wing.

over three times as long as high at the tip. Basal vein and cubitus arising at the same point, the basal vein longer than the oblique apical side of the first discoidal cell. Anal cell with a moderately oblique cross-vein; rather weakly constricted behind basally, but the nervure is strongly thickened at the constriction.

Type. — No. 2040, Mus. Comp. Zoöl., Florissant, Col. (No. 8298, S. H. Scudder Coll.), very nicely preserved except for the hind wings and the antennae.

Eriocampa, sp.

There is a specimen (No. 2041, Mus. Comp. Zoöl.; No. 9101, S. H. Scudder Coll.), which is not well enough preserved to place positively in this genus, but which probably represents a third species. The wings are brown and the body pale, except the posterior margin of the thorax and the last two or three abdominal segments, which are dark or black. It is quite a strikingly colored species.

Emphytus Klug.

This genus is said to be represented in Baltic Amber by Menge ('56).

Paremphytus, gen. nov.

Similar to Emphytus, but the basal nervure and the first recurrent nervure are widely divergent, not parallel as in that genus. The submedian cell is much longer than the median, and the first transverse cubitus absent. Anal cell divided by an oblique nervure; not constricted behind toward the base. Marginal cell very long and unusually narrow beyond the cross-vein; rounded at the tip but not appendiculate. First and second submarginal cells each receiving

a recurrent nervure. Antennae stout and thick, and possibly with the last joint long, as in Arge and its allies. However, this character is not very plainly to be seen on the specimen.

I have not been able to locate this specimen with any degree of satisfaction. The similarity of the antennae to those of Arge *et al.* is very striking, but it is possible that the last joint is in reality several closely united ones. From these forms it differs at once by the non-appendiculate marginal cell and the divided anal cell. The absence of the first transverse cubitus reminds one of Emphytus, but the position of the first recurrent nervure is entirely different.

Paremphytus ostentus, sp. nov.

Female. Length 9 mm. Elongate, black, with indications of brownish bands on the abdomen. Head very small, considerably narrower than the thorax and about one-half as thick as wide. Abdomen with nearly parallel sides; obtusely rounded at the tip where the terebra projects quite distinctly. Wings distinctly infuscated, especially on the apical half. Marginal cell long, divided, gradually narrowed to the tip, which is rounded but not appendiculate. First submarginal

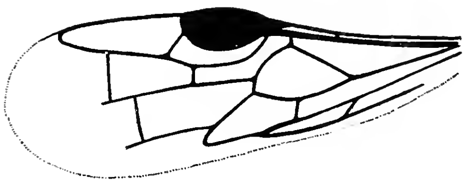

FIG. 6. — *Paremphytus ostentus* Brues. Fore-wing.

cell very long, as long as the second along the radial nervure; second submarginal strongly widened, so that the second transverse cubitus is twice as long as the first. Submedian cell much longer than the median, the basal nervure and the transverse median vein separated on the median vein by a distance almost as great as the length of the basal nervure. Anal cell with an oblique cross-vein.

Type. — No. 2042, Mus. Comp. Zoöl., Florissant, Col. (No. 11,586, S. H. Scudder Coll.).

Pseudosiobla Ashmead.

Cockerell ('07) has described a single species from Florissant. There are none in the material at hand.

Taxonus Hartig.

Two species of Tertiary saw-flies have been referred to this genus. According to Konow, the well-known authority on the classification of these insects, the species described by Heer ('47) as *Tenthredo vetusta* from the lower Miocene at Radoboj is referable to *Taxonus* ('97).

The second species was described by Scudder in his Tertiary Insects ('90) as

Taxonus nortoni from the Green River beds of Wyoming. From his figures (Pl. **10**, Figs. 26-27) of the wing venation there seems to be no doubt that the generic reference is satisfactory.

Palaeotaxonus, gen. nov.

Body elongate, subparallel; the abdomen long, twice the length of the thorax, all its segments of equal width and of nearly equal length. Wing venation as in Taxonus, but the submedian cell is no longer than the median, the transverse median nervure being interstitial with the basal vein. Anal cell divided by an oblique cross-vein which is nearly as long as the transverse median nervure. Marginal cell long, pointed at the tip, divided by an unusually oblique, curved cross-vein. Second and third submarginal cells each receiving a recurrent nervure near the base.

The present form resembles Taxonus in most respects, but differs very plainly in the interstitial transverse median nervure. This is evidently a primitive trait which is exemplified in several of the other fossil saw-flies here described. On this account I have thought the character to be of generic importance, especially taken in connection with its constancy among large groups of recent Hymenoptera.

Palaeotaxonus typicus, sp. nov.

Length 9.5 mm. Head and thorax black, the abdomen more or less rufous or brownish. Head square behind, rounded toward the front, twice as wide as thick. Antennae of equal thickness for at least the basal two-thirds; black; the joints not very well differentiated in the specimen, but one somewhat beyond the middle is about four times as long as thick. Wings hyaline, humeral area with a cross-vein just basad to the origin of the basal vein, which is close to the origin of the

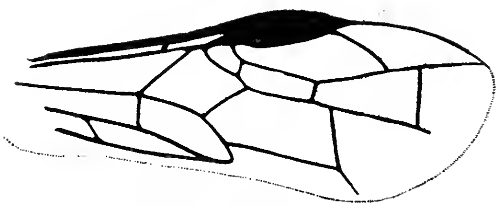

Fig. 7.—*Palaeotaxonus typicus* Brues. Fore-wing.

cubitus. Basal vein and first recurrent nervure almost parallel, slightly convergent behind. First section of the cubitus twice as long as the first transverse cubitus, which is one-third the length of the second submarginal cell. Third submarginal cell over three times as wide at apex as at base.

Described from two specimens.

Type.—No. 2043, Mus. Comp. Zoöl., Florissant, Col. (No. 11,984, S. H. Scudder Coll.). Also, No. 2044, Mus. Comp. Zoöl., Florissant, Col. (No. 7051, S. H. Scudder Coll.).

Dolerus Jurine.

This abundant North American genus has not been found at Florissant, but it is known to occur in the middle Oligocene at Brunstatt in Alsace, where it was noted by Förster (**'91**). Schöberlin (**'88**) has also found it in the upper Miocene in Oeningen.

Macrophya pervetusta, sp. nov.

Length 13 mm. Stout, entirely black, or at least very dark. Head nearly as wide as the thorax, over three times as wide as thick antero-posteriorly, the sides strongly convergent in front. Thorax elongate, twice as long as wide, the metathorax being considerably narrower than the mesothorax. Abdomen nearly as long as the head and thorax together, oval, with six segments clearly defined; rounded broadly at the tip, the extreme apex obscured. Wings hyaline, or perhaps slightly infuscated. Venation typical of the genus, much like that of the recent *M. albicincta*. Marginal cell long, its dividing nervure entering the radius

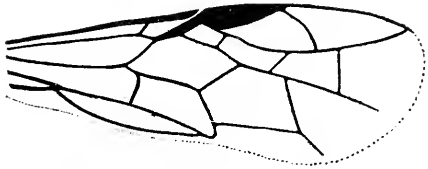

Fig. 8. — *Macrophya pervetusta* Brues. Fore-wing.

much closer to the second transverse cubitus than to the first; first recurrent nervure received just before the middle of the first submarginal cell; the second near the base of the third. Submedian cell but little longer than the median on the externo-medial nervure. Anal cell constricted in the middle until the cross-vein practically disappears; basally it is not appreciably constricted below.

Type. —No. 2045, Mus. Comp. Zoöl., Florissant, Col. (No. 637, S. H. Scudder Coll.).

The venation and the very elongate hind coxae which project backwards laterally so that their tips extend nearly to the middle of the abdomen, determine the systematic position of the species without any doubt. It resembles the present-day *Lagium atroviolaceum* Norton so greatly in size and color that I was tempted to refer it to Lagium. The antennae are not preserved, so that it seems better to refer it to the larger genus Macrophya in absence of positive evidence to the contrary.

Tenthredo Linné.

Four species of Tenthredo, *sensu stricto*, have been discovered at Florissant, one recently described by Cockerell, and three characterized in the present paper.

Brischke (**'86**) has recognized a species in Baltic amber which he has not described, and Gravenhorst (**'35**) also noted the occurrence of the genus in the same formation.

Less exact references have been made to Tenthredo by Schöberlin (**'88**), two species from Oeningen; Serres (**'29**) and Heer (**'61**), species from Aix; and Schlotheim (**'29**), one from Baltic amber. These last cannot be regarded as generic determinations, and have no especial significance in the present state of our knowledge.

Florissant species of Tenthredo.

1. Anal cell of hind wings sessile with or touching the first apical cell; discoidal cell of front wings very long, its diagonal length much more than twice the length of the basal nervure . . . . *T. avia*, sp. nov.
   Anal cell of hind wings shorter, not touching the first apical cell, but separated from it by a distinct vein or petiole 2
2. Petiole of anal cell in hind wing over one-half the length of the basal nervure of the front wing, equalling the vein closing the second discoidal cell of hind wing . . . . *T. infossa*, sp. nov.
   Petiole of anal cell very short, less than one-third the length of the basal nervure 3
3. Length 13 mm. First discoidal cell over four times as long as the basal nervure in the front wing . . . . *T. submersa* Ckll.
   Length 17 mm. First discoidal cell less than three times as long as the basal nervure . . . . *T. misera*, sp. nov.

Tenthredo avia, sp. nov.

Female. Length about 13 mm. Body probably variegated with yellow and black. The head is black and the antennae dark. Dorsum of thorax brownish black at the bases of the wings and paler along the parapsidal furrows. Scutellum yellowish; metanotum yellowish, with black reticulations. Median groove of mesonotum very distinct. Abdomen apparently very pale, with a dorsal line of spots, one to each segment; these are small, rounded-quadrate, and diminish in size apically. Wings hyaline, the veins unusually pale in color. Median cell shorter than the submedian by only one-half the length of the transverse median nervure. Third submarginal cell more than twice as high at the apex as at the base. Anal cell not contracted at the insertion of the cross-vein; its sides subparallel, but the posterior side suddenly widens out basally, making the cell more than twice as wide as at the cross-vein. Posterior wing with the anal cell not separated from the first apical cell by a vein.

Type. — No. 2046, Mus. Comp. Zoöl., Florissant, Col. (No. 3763, S. H. Scudder Coll.).

Of the four species from the Florissant shales, this most closely approaches recent representatives of the genus. The preservation of the type is very good, except the sides of the abdomen, which are not distinguishable at first glance. This causes the abdomen to take on a singular subulate appearance quite foreign to its actual form.

Tenthredo infossa, sp. nov.

Length 10.5 mm. Probably a female. Body stout; dark in color. Head black, the thorax more or less light colored anteriorly; the scutellum and metanotum black. Abdomen very dark, narrowly banded with pale on the sutures. Wings hyaline, the veins unusually dark. Antennae black, the apical three joints narrowing; basal joints rather broad, the ones at the beginning of the flagellum three or four times as long as thick. Head small and broad, two and one-half times as wide at the temples as thick antero-posteriorly. Abdomen narrowly oval, twice as long as wide; the extreme apex not preserved, so that the sex cannot be positively determined. Marginal cell moderately long, its cross-vein only slightly curved; first discoidal cell unusually short, hardly more than twice as long diagonally as the length of the basal vein, and more rhombic in

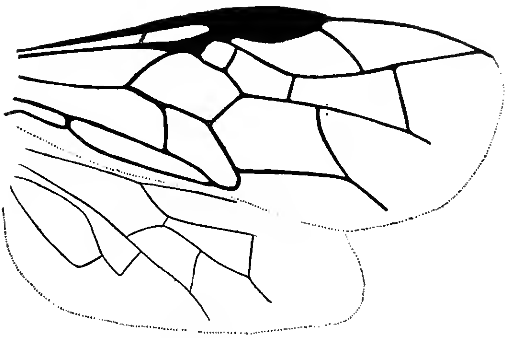

FIG. 9. — *Tenthredo infossa* Brues. Wings.

shape than usual. First submarginal cell quadrate, the first abscissa of the cubitus but little longer than the first transverse cubitus. Submedian cell longer than the median by a little more than the length of the transverse median nervure. Second submarginal cell receiving the recurrent nervure distinctly before the middle. Anal cell slightly constricted at the cross-vein, suddenly widened out behind toward the base to nearly triple its width at the cross-vein. Petiole at apex of anal cell in hind wing as long as the vein closing the second discoidal cell.

Type. — No. 2047, Mus. Comp. Zoöl., Florissant, Col. (No. 11,988, S. H. Scudder Coll.).

One specimen in a fine state of preservation.

This species resembles Macrophya to some extent, more especially on account of the petiolated anal cell of the hind wing, but the form of the anal cell in the front wing is that of Tenthredo. The legs are not at all preserved.

Tenthredo misera, sp. nov.

Female. Length 17 mm. Large and robust; head and thorax dark, probably the head was black and the thorax black, varied more or less with brown. Abdomen pale, very indistinctly indicated in the fossil. Head about two and one-half times as wide as thick. Antennae slender and tapering very gradually to the tip, the joints toward the base of the flagellum three or four times as long as wide. Wings hyaline, the veins rather weak and light in color. Marginal cell long, its cross-vein distinctly arcuate. First submarginal cell considerably narrowed above, the first section of the cubitus being nearly two times as long as the first section of the radius. Second submarginal cell receiving the recurrent nervure at its basal third. Submedian cell longer than the median by somewhat more than the length of the transverse median nervure. First discoidal cell diagonally about two and one-fourth times as long as the basal vein. Anal cell constricted imperceptibly at the cross-vein, and slowly widened basally behind; the cross-vein is distinctly oblique. Petiole at apex of anal cell in hind-wing only one-fourth as long as the vein closing the second discoidal cell.

Type. — No. 2048, Mus. Comp. Zoöl., Florissant, Col. (No. 12,400, S. H. Scudder Coll.).

This is by far the largest species of Tenthredo here described.

LYDIDAE.

Atocus Scudder.

This genus was erected by Scudder ('92) for a single species from Florissant. It comes very close to Neurotoma and Pamphilius as defined by Konow (:05). The only noteworthy character that separates it is the uniformly decreasing length of the antennal joints, the third, or first flagellar, joint being distinctly longer than the second in recent forms. If this character has been overlooked in figuring the type, it can scarcely be considered distinct from Neurotoma, to which it is more closely related than to Pamphilius (= Liolyda) on account of the absence of the humeral cross-vein.

Electrocephalus Konow.

This genus was proposed by Konow ('97) for a single species from Baltic amber. It is related to Janus and Macrocephus.

Cephus Latreille.

An amber species is noted by Menge ('56), but no other fossil forms have been described or mentioned so far as I am aware.

Megaxyela petrefacta, sp. nov.

Female. Length probably about 13 mm., the head nearly effaced. Dark in color, with the sutures of the abdomen pale on the sides; these markings are narrow near the base, but occupy the major parts of the several apical segments. Terebra exserted $1\frac{1}{2}$ mm., curved downward to the blunt tip. The abdomen is somewhat cylindrical and slowly narrowed to near the tip, when it suddenly rounds down to the base of the terebra. The head, antennae, thorax, and legs are not well enough preserved for description, but the wings show clearly their venation, although somewhat overlapped in position. The type is very similar to that of *Megaxyela major* Cresson. The first marginal cell, however, lying just beneath the stigma, is nearly twice as long as wide, and the first recurrent nervure

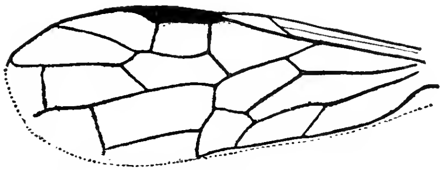

FIG. 10. — *Megaxyela petrefacta* Brues. Fore-wing.

is only two-thirds as long as the vein that meets it to form the tip of the second discoidal cell. Otherwise the venation so far as preserved is scarcely distinguishable from the recent species.

Type. — No. 2049, 2050 (reverse), Mus. Comp. Zoöl., Florissant, Col. (No. 1386, 4295, S. H. Scudder Coll.).

Due to splitting of the rock and subsequent weathering, only the abdomen and wings are preserved, although the entire length can be made out. In venation and size this species is remarkably similar to *M. major* Cresson, from Texas, of which it is undoubtedly a close relative. So far no other recent species have been discovered, and the genus appears to be restricted to the southwestern United States.

SIRICIDAE.

Paururus Konow.

According to Konow (:05) the fossil described by Heer as *Urocerites spectabilis* from the lower Miocene of Radoboj belongs to this recent genus, and must be known as *Paururus spectabilis* Heer.

Sirex Linné.

Two species referred to this genus have been recognized in Baltic amber by Klebs ('89).

Lithoryssus parvus Brues.

There are three specimens of this species in the present collection (No. 2051–2054, Mus. Comp. Zoöl., Florissant, Col., No. 5080, 5110 (reverse), 5522, and 14,045, S. H. Scudder Coll.), none of them so perfectly preserved as the type, however, which is in the American Museum of Natural History. In one the wings are better preserved, and I find that the humeral area is divided by a cross-vein just before the origin of the basal nervure, and not "apparently undivided," as stated in the original description of the species (:06). In size they are all larger than the type, 4–5 mm., but seem otherwise identical.

Cephites Heer.

Two species, *C. oeningensis* and *C. fragilis* Heer, have been placed in this genus by Heer ('47), who considers them to be related to Cephus and Xiphydria.[1]

The front wings have two radial cells, the first under but extending beyond the stigma; the first submarginal cell is large, seven-sided, and touches the stigma; second longer and narrower; those beyond, if any, obliterated. Two discoidal cells, the first distinct and moderately large, rhomboidal; the following (third) open apically where the neuration becomes obsolete. Humeral area narrow but distinct. Basal cell wider, the transverse median nervure present.

From this diagnosis it will be seen that Cephites approaches Lithoryssus in many respects, and in view of the fact that such close relationship prevails between many of the Florissant and Oeningen types, it is not unlikely that the two may be quite similar. I have therefore placed the European form near Lithoryssus, tentatively at least.

[1] Konow ('97) believes that these are Neuroptera, but Handlirsch (:07) does not agree with him, and thinks that they have been correctly placed by Heer. Not having had access to any specimens, and thus compelled to rely on Heer's figures, I have merely pointed out the resemblance which they apparently show to the American Lithoryssus.

CATALOGUE OF TERTIARY PHYTOPHAGA.

Tenthredinidae.

Trichiosomites obliviosus Brues.
Bull. M. C. Z., 1908, **51**, p. 260.
Miocene; Florissant, Colorado.

Cimbex (larva) Menge.
Progr. petrischule Danzig, 1856, p. 24.
Lower Oligocene; Baltic Amber.

Phenacoperga coloradensis Ckll.
Science, 1907, n. s., **26**, p. 446 (*Perga*); *idem*, 1908, **27**, p. 113.
Miocene; Florissant, Colorado.

Lophyrus, sp. Brischke.
Schrift. naturf. gesellsch. Danzig, 1886, n. f., **6**, p. 279.
Lower Oligocene; Baltic Amber.

Hemichroa eophila Ckll.
Bull. Amer. mus. nat. hist., 1906, **22**, p. 501.
Miocene; Florissant, Colorado.

Dineura saxorum Ckll.
Bull. Amer. mus. nat. hist., 1906, **22**, p. 499.
Miocene; Florissant, Colorado.

Dineura laminarum Brues.
Bull. M. C. Z., 1908, **51**, p. 261.
Miocene; Florissant, Colorado.

Pteronus, sp. Serres.
Géogn. terrains tert., 1829, p. 229.
Lower Oligocene; Aix, France.

Pteronus prodigus Brues.
Bull. M. C. Z., 1908, **51**, p. 262.
Miocene; Florissant, Colorado.

Scolioneura vexabilis Brues.
Bull. M. C. Z., 1908, **51**, p. 263.
Miocene; Florissant, Colorado.

Selandria, sp. Brischke.
Schrift. naturf. gesellsch. Danzig, n. f., 1886, **6**, p. 279.
Lower Oligocene; Baltic Amber.

Selandria (*Tenthredo*), sp. Curtis.
Edinburgh new philos. journ., 1829, **7**, p. 295.
Lower Oligocene; Aix, France.

Eriocampa wheeleri Ckll.
Bull. Amer. mus. nat. hist., 1906, **22**, p. 500.
Miocene; Florissant, Colorado.

Eriocampa scudderi Brues.
Bull. M. C. Z., 1908, **51**, p. 264.
Miocene; Florissant, Colorado.

Emphytus, sp. Menge.
Progr. petrischule Danzig, 1856, p. 24.
Lower Oligocene; Baltic Amber.

Paremphytus ostentus Brues.
Bull. M. C. Z., 1908, **51**, p. 265.
Miocene; Florissant, Colorado.

Pseudosiobla megoura Ckll.
Bull. Amer. mus. nat. hist., 1907, **23**, p. 612.
Miocene; Florissant, Colorado.

Taxonus nortoni Scudder.
Tert. ins. N. Amer., 1890, p. 604.
Oligocene; Green River, Wyoming.

Taxonus vetustus Heer.
Insectenf. tertiärg. Oeningen, 1849, **2**, p. 172 (*Tenthredo*).
Konow, Ent. nachr., 1897, **23**, p. 36 (Taxonus).
Upper Miocene; Oeningen.

Palaeotaxonus typicus Brues.
Bull. M. C. Z., 1908, **51**, p. 266.
Miocene; Florissant, Colorado.

Dolerus, sp. Schöberlin.
Soc. entom., 1888, **3**, p. 61.
Upper Miocene; Oeningen.

Dolerus tenax Förster.
Abh. geol. spezialk. Els., 1891, p. 453.
Middle Oligocene; Brunstatt, Alsace.

Macrophya pervetusta Brues.
Bull. M. C. Z., 1908, **51**, p. 267.
Miocene; Florissant, Colorado.

Tenthredo, sp. Serres.[1]
Géogn. terrains tert., 1829, p. 229.
Lower Oligocene; Aix, France.

[1] Compared with *T viridis* L., which is now referred to the genus Rhogogastera Konow.

Tenthredo, sp. Schlotheim.
Petrefactenkunde, 1820, p. 43.
Lower Oligocene; Baltic Amber.

Tenthredo, sp. Gravenhorst.
Uebers. schles. gesellsch. vaterl. cult., 1835, p. 92.
Lower Oligocene; Baltic Amber.

Tenthredo, sp. Brischke.
Schrift. naturf. gesellsch. Danzig., 1886, n. f., **6**, p. 279.
Lower Oligocene; Baltic Amber.

Tenthredo, sp. Schöberlin.
Soc. entom., 1888, **3**, p. 61.
Upper Miocene; Oeningen (two species).

Tenthredo gervaisi Heer.
Saporta, Rech. climat. pays tert., 1861, p. 153.
Lower Oligocene; Aix, France.

Tenthredo submersa Ckll.
Bull. Amer. mus. nat. hist., 1907, **23**, p. 613.

Tenthredo avia Brues.
Bull. M. C. Z., 1908, **51**, p. 268.
Miocene; Florissant, Colorado.

Tenthredo infossa Brues.
Bull. M. C. Z., 1908, **51**, p. 269.
Miocene; Florissant, Colorado.

Tenthredo misera Brues.
Bull. M. C. Z., 1908, **51**, p. 270.
Miocene; Florissant, Colorado.

Lydidae.

Atocus defessus Scudder.
Bull. 93, U. S. G. S., 1892, p. 24, pl. 11, f. 5.
Cockerell, Science, 1907, n. s., **27**, p. 113.
Miocene; Florissant, Colorado.

Pamphilius, sp. (larva) Menge.
Progr. petrischule Danzig, 1856, p. 24.
Lower Oligocene; Baltic Amber.

Electrocephalus strahlendorffi Konow.
Ent. nachr., 1897, **23**, p. 37.
Lower Oligocene; Baltic Amber.

Cephus, sp. Menge.
Progr. petrischule Danzig, 1856, p. 24.
Lower Oligocene; Baltic Amber.

Megaxyela petrefacta Brues.
Bull. M. C. Z., 1908, **51**, p. 271.
Miocene; Florissant, Colorado.

Siricidae.

Paururus spectabilis Heer.
Neue denkschr. schweitz. gesellsch., 1867, **22**, p. 38.
Lower Miocene; Radoboj.

Sirex, 2 spp. Klebs.
Tagbl. naturforschervers., 1889, **62**, p. 269.
Lower Oligocene; Baltic Amber.

Lithoryssus parvus Brues.
Bull. Amer. mus. nat. hist., 1906, **22**, p. 492. fig. 1.
Miocene; Florissant, Colorado.

Cephites fragilis Heer.
Insektenf. tertiärg. Oeningen, 1849, **2**, p. 174.
Upper Miocene; Oeningen.

Cephites oeningensis Heer.
Insektenf. tertiärg. Oeningen, 1849, **2**, p. 173.
Upper Miocene; Oeningen.

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Recherches sur le climat et la vegetation du pays tertiaire. Genève et Paris.

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Ueber fossile blatt- und halmwespen. Ent. nachr., **23**, p. 36–38.

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AT HARVARD COLLEGE.

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SOME JAPANESE AND EAST INDIAN ECHINODERMS.

By Hubert Lyman Clark.

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No. 11. — *Some Japanese and East Indian Echinoderms.* By HUBERT LYMAN CLARK.

THE Museum of Comparative Zoölogy received in the autumn of 1907 a collection of Echinoderms made by Mr. Thomas Barbour at Amboina and several other islands in the Dutch East Indies, including Dutch New Guinea. There are 362 specimens in this collection, representing thirty-two species, and while none of them is new to science, some are new to the Museum collection and many are of interest because of the localities where they were collected. The value of these specimens is greatly enhanced by Mr. Barbour's notes on their color, habitat, and appearance in life.

From Mr. Alan Owston the Museum has purchased an interesting lot of Echinoderms, consisting of 153 specimens, representing forty species, of which eight are new to science. The following pages give an annotated list of the seventy species contained in these collections and indicated as the Barbour collection and the Owston collection respectively, arranged systematically, with descriptions of the new forms.

CRINOIDEA.

Tropiometra macrodiscus.

Antedon macrodiscus Hara, 1895. Zoöl. Mag., Tokyo, **7**, p. 115.
Tropiometra macrodiscus A. H. Clark, 1907. Smiths. Misc. Coll., **50**, p. 349.

1 specimen, in excellent condition, about 450 mm. in diameter. Color in alcohol uniform deep yellow. Misaki, Sagami Bay, Japan. Owston collection. Kindly identified by Mr. A. H. Clark.

Cyllometra manca.

Antedon manca P. H. Carpenter, 1888. Challenger Reports, **26**, p. 226.
Cyllometra manca A. H. Clark, 1907. Smiths. Misc. Coll., **50**, p. 357.

1 specimen, about 90 mm. in diameter. Color in alcohol pale purple; arms banded with whitish. Uraga Channel, Gulf of Tokyo, Japan; 20–30 fathoms. Owston collection.

ASTEROIDEA.

Archaster typicus.

Müller & Troschel, 1840. Monatsb. Akad. Wiss., Berlin, p. 104.

60 specimens, 60–125 mm. in diameter. Saonek, Waigiou Island, New Guinea. — 45 specimens, 50–120 mm. in diameter. Amboina. Barbour collection.

According to Mr. Barbour's notes, these specimens were taken in very shallow water on a bottom of white sand. The color in life was orange-red, but in drying the specimens nearly all trace of this color was lost, and they became pale yellowish, with only here and there patches of orange-red. One of the specimens from Amboina has 6 rays, while two of those from Saonek have only 4 rays each.

Oreaster nodosus.

Asterias nodosa Linné, 1758. Syst. Nat., ed. 10, p. 661.
Oreaster nodosus Bell, 1884. Proc. Zoöl. Soc. London, p. 70.

18 specimens, Humboldt Bay, New Guinea. — 5 specimens, Sorong, New Guinea. — 3 specimens, Ansus, Jappen Island, New Guinea (135° 44′ E. × 1° 47 S′.). — 1 specimen, Amboina. Barbour collection.

These specimens range from 80 to 300 mm. in diameter and exhibit the greatest diversity in the development of the great tubercles so characteristic of this species. In the youngest specimen there are present 15 tubercles, one at each radial corner of the disc and two on the ridge of each ray; those on the disc are largest and most nearly pointed, while those nearest the tips of the rays are small and nearly spherical. In specimens a trifle older there are 20 or 25 tubercles, one or two more having developed on each ray. The pair of tubercles which are found in large specimens at the proximal end of the rays, one on each side of the ridge, are first seen in an individual 165 mm. in diameter, but are quite small and rounded, and it is only in much larger specimens that they are fully developed. The tubercle at the centre of the disc is present in only six specimens, and none of these is under 200 mm. in diameter. In the largest individual it is wanting, but there are 72 tubercles, arranged as follows: one large one, with two or even three points, at each radial angle of the disc; one rather small but pointed one in each interradius not far from the margin, and in one interradius there are two such tubercles; eight on the ridge of each ray, with a ninth on two of the rays; the usual pair at the base of each ray; and one, two, or even three extra tubercles on the sides of the rays near the base. No less than 20 of the tubercles terminate in two, three, or even four sharp, bare points. — In life, the color of this species shows considerable diversity, ranging from clay-color with the large tubercles muddy brown, or with the large tubercles deep red-brown, becoming vermilion at the base, or with the large tubercles black, with their bases, the tips of the

arms, and the centre of disc claret-red, to a nearly uniform vermilion-red all over. Most of the dried specimens were dirty yellowish, but on being washed with alcohol the vermilion-red color returned to a greater or less degree in different individuals and has not been lost by subsequent drying. The largest specimen (300 mm.) from Amboina is the most uniform and the brightest vermilion. — This species was found chiefly on bottoms where there was more or less vegetation or in open places about coral reefs.

Culcita novae-guineae.

Müller & Troschel, 1842. Sys. Ast., p. 38. *Goniodiscus sebae* Müller & Troschel, 1842. Sys. Ast., p. 58.

3 specimens, 80–130 mm. in diameter. Sorong, New Guinea. — 1 specimen, 75 mm. in diameter. Amboina. Barbour collection.

The small series of Culcitas brought home by Mr. Barbour is of great interest because they prove that the starfish hitherto known as *Goniodiscus sebae* is the young of *Culcita novae-guineae* and not a distinct species closely related to the ancestral stock from which Culcita has sprung, as Döderlein has so ably argued (Semon's Zool. Forsch. Aust., **5**, lf. 4, p. 489–504). The specimen from Amboina is clearly *Goniodiscus sebae*, agreeing not only with Müller and Troschel's description, but with de Loriol's (1885. Mém. Soc. Phys., Genève, **29**, p. 48; Plate 15, figs. 6–6e) description and figures, and with specimens in the Museum of Comparative Zoölogy collection from the Gilbert and Marshall Islands. It cannot, however, be separated in any way from the slightly larger young Culcita from Sorong, which is certainly identical with the other two specimens. On the actinal side the latter are exactly like Döderlein's (1896. Semon's Zool. Forsch. Aust., **5**, lf. 3, p. 301–322) figures (Plate 20, fig. 9) of *C. novae-guineae*, but abactinally one is like *C. n. plana* (Plate 19, fig 1), while the other (the largest of all) is like *C. n. arenosa* (Plate 19, fig. 5). Judging from the 54 Culcitas accessible to me, it seems doubtful whether the varieties (or subspecies) of *C novae-guineae*, so carefully worked out by Döderlein, are really sufficiently distinct to warrant their recognition. — Mr. Barbour's specimens were collected about the reefs and were of a yellowish-brown color, with something of an olive tint when alive. They were all flat and more or less discoidal in life and showed no tendency to the spherical form characteristic of many adult Culcitas.

Gymnasteria carinifera.

Asterias carinifera Lamarck, 1816. Anim. s. Vert., **2**, p. 556.
Gymnasterias carinifera v. Martens, 1866. Arch. f. Naturg., **32** (1), p. 74.

1 specimen, 130 mm. in diameter. Yellowish brown (dried). Sorong, New Guinea. Barbour collection.

Asterina cepheus.

Asteriscus cepheus Müller & Troschel, 1842. Sys. Ast., p. 41.
Asterina cepheus v. Martens, 1866. Arch. f. Naturg., **32** (1), p. 85.

2 specimens, 33 mm. in diameter. Amboina. Barbour collection.

In life these specimens were bluish green above, pale yellowish beneath, and these colors were little changed by drying. But on being washed with alcohol, the blue-green color was changed to orange-red, which faded to reddish-yellow on drying.

Asterina exigua.

Asterias exigua Lamarck, 1816. Anim. s. Vert., **2**, p. 554.
Asterina exigua Perrier, 1876. Arch. Zoöl. Exp., **5**, p. 222.

1 specimen, 30 mm. in diameter. In life dark fawn-color; pale in dried specimen. Under a stone, Tifu Bay, Buru Island, Moluccas. Barbour collection.

Asterina pectinifera.

Asteriscus pectinifer Müller & Troschel, 1842. Sys. Ast., p. 40.
Asterina pectinifera v. Martens, 1865. Arch. f. Naturg., **31** (1), p. 352.

2 specimens, Misaki, Sagami Bay, Japan. — 3 specimens, Tokyo, Japan. Owston collection.

These specimens are 68–90 mm. in diameter, and the color in alcohol is a more or less indistinct orange-red, which becomes paler on drying.

Linckia laevigata.

Asterias laevigata Linné, 1758. Syst. Nat., ed. 10, p. 662.
Linckia laevigata Lütken, 1871. Vid. Med., p. 265.

32 specimens, Amboina. — 6 specimens, Sorong, New Guinea. — 3 specimens, Gani, Halmaheira Island. — 2 specimens, Manokwari, New Guinea. — 1 specimen, Pom, Jappen Island, New Guinea. Barbour collection.

These specimens were all collected on sandy bottoms and were blue, ranging from bright cobalt to brownish blue, with the papular areas more or less distinctly yellow. They were taken directly from the salt water and dried by artificial heat, so that in most cases there has been little change in form or color. They range from 85 to 265 mm. in diameter. Three of those from Amboina have only four rays each. The specimen from Pom has two madreporites but is not otherwise peculiar in any way. Examination of a very large series of specimens (343) in the Museum collection, from twenty stations between the Persian Gulf and Zanzibar on the west, and Samoa and Hawaii on

the cast, has satisfied me that it is futile to attempt to separate *L. multifora* from *laevigata* by any constant characters, although typical examples of the two forms are so easily distinguished. Specimens under 75 mm. in diameter usually show the characters of *multifora*, but in fully grown specimens all intergradations occur between the broad-rayed *laevigata* and the slender-rayed *multifora*. Unfortunately the number of madreporites is worthless as a character, for broad-rayed specimens occasionally have two, while slender-rayed specimens very often have only one. Most specimens from the western part of the Indo-Pacific region seem to have the rays long and slender, while most of those from Australia and the Pacific Islands have the rays short and broad, but this is far from being invariably true. On the whole I think we may retain *multifora* only as a form or variety of *laevigata*. The specimens in the Barbour collection showed a most extraordinary change in color when washed with alcohol. A few were placed in a jar of alcohol, which had been previously used, and their blue tints immediately became vivid orange-red. Thinking the change might be caused by impurities in the alcohol, further experiments were made, which showed that the effect is produced by the alcohol itself, and the mere application of perfectly pure alcohol for a few seconds is sufficient to change a bright blue color to bright orange-red. Subsequent application of an alkali had no visible effect. Continued immersion in alcohol results in the gradual loss of red, the specimens becoming brownish-yellow. On drying, the red specimens seem to retain the color quite well. In the lot of specimens from Amboina there are now to be seen brownish-blue, blue, orange-red, reddish-yellow, and brownish-yellow individuals. These facts emphasize the rule that little importance can be attached to differences in color shown by museum specimens of starfish. — One of the specimens from Amboina and one of those from Manokwari, each bore a specimen of the peculiar gasteropod, *Thyca pellucida*, described by Kükenthal in 1897 as found by him on specimens of Linckia at Ternate (see his "Parasitische Schnecken," Abh. Senck. Nat. Ges., **24** (1), p. 7; Plate 2, figs. 7–9).

Nardoa tuberculata.

Gray, 1840. Ann. Mag. Nat. Hist., **6**, p. 287.

5 specimens, 130–215 mm. in diameter. Sorong, New Guinea. Barbour collection.

These specimens were found on sandy patches among the reefs and in life were a fawn-brown, which in dried specimens has become deep tawny brown, more or less blotched with blackish abactinally on the rays. They agree with de Loriol's (1893) specimens from Amboina in the entire absence of the dusky cross-bands on the rays shown in Herklot's (1868) figure. One of the specimens has only a very few of the characteristic tubercles developed.

Pteraster obesus, sp. nov.

Rays 5. R = 22 mm., r = 16 mm., R = 1.4 r. Breadth of ray at base, 16 mm. Interbrachial arcs shallow. Disc high, vertical diameter, 16 mm.; rays

not clearly marked off. Abactinal surface of rays high, rounded; actinal surface somewhat flat. Distal end of ray upturned, so that ambulacral furrows terminate on abactinal surface. Supradorsal membrane rather thin with no sign of reticulations. Spiracula small but very abundant all over abactinal surface. Paxillae high with numerous spines (8–10 or more) of approximately equal size. About 30 of the paxillae have the spines longer and stouter than the others, and these push the membrane up into more or less conspicuous points or ridges, which are irregularly scattered and give the abactinal surface a rough, almost warty appearance. Apparently there are no other calcareous particles in the membrane. Osculum large, surrounded by about 50 closely webbed long spines, which nearly close it. Ambulacra of moderate width; feet in two rows. Adambulacral plates, each with six (near the mouth there may be seven) spines, the innermost much the smallest, the outermost longest; as the innermost is situated on the inner aboral corner of the plate and the others are on its adoral side, the series is distinctly curved, with the concavity away from the mouth; all the spines are united to each other and to the actino-lateral spine by a membrane which reaches nearly to their free ends, but from which they project distinctly. Actino-lateral spines short, only about half as long again as the outermost adambulacral spine; as they are approximately equal except at tip of ray, the actino-lateral "fringe" is narrow and nearly parallel-sided, and is thus completely concealed from above; aperture-papilla small, free only along its aboral edge. Mouth-plates large, decidedly elevated at their aboral ends, where they terminate in a conspicuous point; the points of the adjacent plates are closely appressed, so there is only one point for the two plates. Each plate bears on its margin 5–7 (usually 6) spines, of which the first is about as long as the plate, flat, about one-fourth as wide as long, and square-cut at the end; the second is about two-thirds as long and, although flat, is somewhat more tapering; the remaining 3–5 spines are very slender, pointed, and about half as long as the first; the spines are all free, no membrane being developed between them. On the surface of each mouth-plate, at about the centre, is a very conspicuous superoral spine; it is longer and much stouter than the first mouth-spine, and terminates in a heavy, sharp, triangular point. — Color of alcoholic specimen, purplish pink, lightest on the ambulacra.

1 specimen from Sagami Bay, Japan; 35° N. × 138° 48′ E., 75 fathoms. Owston collection.

Pteraster multiporus, sp. nov.

Rays 5. R = 16 mm., r = 10 mm., R = 1.6 r. Breadth of ray at base 11 mm. Interbrachial arcs rather deep and angular. Disc moderately high, vertical diameter 8.5 mm.; rays not well marked off. Abactinal surface of rays rather high, rounded; actinal surface flat. Distal end of ray upturned so that ambulacral furrows terminate on abactinal surface. Supradorsal membrane thin, very indistinctly reticulated. Spiracula small but exceedingly numerous all over the abactinal surface. Paxillae low, with numerous spines (8–10 or more), which are

much longer than the stalk that bears them; these spines are slender and approximately equal, so that the entire abactinal surface is relatively smooth. Aside from the tips of these spines there do not appear to be any calcareous particles in supradorsal membrane. Osculum rather small, surrounded by 30–40 rather short, closely webbed spines. Ambulacra rather narrow; feet in two rows. Adambulacral plates each with five (sometimes six) spines, the innermost much the smallest, the outermost longest; as the innermost is situated on the inner aboral corner of the plate and the others are on its adoral side, the series is distinctly curved, with the concavity away from the mouth; all the spines are united to each other and to the actino-lateral spine by a membrane which reaches nearly to their free ends, but from which they project distinctly. Actino-lateral spines short, little longer than outermost adambulacral spine, flattened and widened at the bluntly-rounded tip; they are subequal and the actino-lateral "fringe" is accordingly narrow and nearly parallel-sided. Aperture-papilla small, free only along aboral edge. Mouth-plates moderate, each with six slender, nearly cylindrical but pointed spines along the margin, the innermost largest, outermost smallest; the entire group of twelve spines is completely united by a thin but conspicuous membrane; superoral spines moderately stout, cylindrical but pointed, slightly exceeding the longest oral spines. — Color of alcoholic specimen, purplish pink.

1 specimen from Sagami Bay, Japan; 35° N. × 138° 48′ E., 75 fathoms. Owston collection. Although taken at the same station with *obesus*, it is an entirely distinct species. It is closely allied to *reticulatus* from the Hawaiian Islands, but differs in having webbed oral spines, short, broad, actino-lateral spines, and low paxillae.

List of the species of Pteraster.

militaris O. F. Müller, 1776. Zoöl. Dan. Prod., p. 234. North Atlantic and Arctic Oceans, 10–618 fathoms.

pulvillus M. Sars, 1861. Overs. Norg. Ech., p. 62. North Atlantic and Arctic Oceans, 20–80 fathoms.

danae Verrill, 1869. Proc. Bost. Soc. Nat. Hist., **12**, p. 386. Atlantic Ocean off east coast of South America, 30(?)–55 fathoms.

affinis Smith, 1876. Ann. Mag. Nat. Hist., (4) **17**, p. 108. Royal Sound, Kerguelen Island, 5–28 fathoms.

caribbaeus Perrier, 1883. Stell. du "Blake," p. 216. Subtropical western Atlantic Ocean, 151–422 fathoms.

aporus Ludwig, 1886. Zool. Jahrb., **1**, p. 293. Behring Sea.

rugatus Sladen, 1889. Challenger Report, **30**, p. 473. Antarctic Ocean, vicinity of Heard Island, 150 fathoms.

semireticulatus Sladen, 1889. Challenger Report, **30**, p. 475. Antarctic Ocean, near Marion Island, 69 fathoms.

stellifer Sladen, 1889. Challenger Report, **30**, p. 474. Antarctic Ocean, near Cape Horn, 245 fathoms.

personatus Sladen, 1891. Proc. Roy. Irish Acad., (3) **1**, p. 694. Atlantic Ocean, off Irish coast, 750 fathoms.

ingoufi Perrier, 1891. Ech. Cap Horn, p. K 144. Antarctic Ocean, near Cape Horn, 150 fathoms.

lebruni Perrier, 1891. Ech. Cap Horn, p. K 145. Antarctic Ocean, near Cape Horn and further south, 45–250 fathoms.

alveolatus Perrier, 1894. Tal. et Trav. Ech.: Stell., p. 183. Atlantic Ocean, near Azores, 2256 fathoms.

sordidus Perrier, 1894. Tal. et Trav. Ech.: Stell., p. 182. Atlantic Ocean, off Morocco, 633 fathoms.

multispinus Clark, 1901. Proc. Bost. Soc. Nat. Hist., **29**, p. 326. Puget Sound.

jordani Fisher, 1905. Bull. Bur. Fish., **24**, p. 314. Eastern Pacific Ocean, off San Diego, Cal., 642–650 fathoms.

reticulatus Fisher, 1906. Starfishes Haw. Isl., p. 1098. Pacific Ocean, near Hawaiian Islands, 284–298 fathoms.

obesus Clark, supra.

multiporus Clark, supra.

Key to the species of Pteraster.

Form more or less stellate, $R > 1.8\,r$, usually 2–3.5 r.
- A stout spine (superoral) present on surface of each oral plate.
  - A more or less conspicuous opening (osculum) present in centre of abactinal surface.
    - Adambulacral comb with more than 5 spines.
      - Stalk of paxilla short, not much higher than thick; oral spines 6, similar, none so large as superoral . . . . *militaris.*
      - Stalk of paxilla high and slender; oral spines 5, innermost much the largest, larger than superoral . . . . *caribbaeus.*
    - Adambulacral comb with 3–5 spines.
      - Oral spines 6; supradorsal membrane thick and smooth . . . *lebruni.*
      - Oral spines 4; supradorsal membrane thin.
        - Paxillae with numerous (5–10) spinelets; superoral spine shorter and stouter than innermost oral; 4 well-developed adambulacral spines *affinis.*
        - Paxillae with few (1–3) spinelets, of which one is very long; superoral spine long, equalling innermost oral; innermost of 4 adambulacral spines very small or wanting . . . . *jordani.*
  - No osculum present . . . . *aporus.*
- No superoral spine present.
  - Adambulacral spines 5, in curved series; oral spines 5 . . . . *personatus.*
  - Adambulacral spines 4, in straight series; oral spines 6 . . . . *sordidus.*

Form more or less pentagonal, $R < 1.8\,r$, usually 1.3–1.7 r; superoral spine present.
- Adambulacral armature of 6–7 spines; paxillae spinelets 8–15.
  - Abactinal surface more or less swollen and rough or warty in adult; oral spines 6 (5–7).

Oral spines rather slender, all united by membrane; superoral spine not stout and triangular-pointed; actino-lateral spines much longer near middle of ray than near tip . . . . *pulvillus.*
Oral spines not united by membrane; first two (innermost) very flat and truncate; superoral spine very stout and triangular-pointed; actino-lateral spines of approximately equal length except at very tip of ray . *obesus.*
Abactinal surface not much elevated and not at all warty.
Oral spines 3, united by membrane; $R = 1.5\ r\pm$ . . . . . *multispinus.*
Oral spines 6 or 7, not united by membrane; $R = 1.7\ r\pm$ . . *reticulatus.*
Adambulacral armature of 3–5 (rarely 6) spines.
Oral spines 6.
2 innermost spines long, 4 lateral short, each group united by a web; thus 4 groups to each mouth angle; adambulacral spines usually 4; no spiracula . . . . *alveolatus.*
Oral spines of each mouth angle all (12) united by a common membrane into a single group; adambulacral spines usually 5; spiracula very abundant . . . . *multiporus.*
Oral spines 3–5.
Oral spines not united by a web.
Adambulacral spines short, scarcely projecting beyond web . . *stellifer.*
Adambulacral spines slender, projecting far beyond web . . . *danae.*
Oral spines united together by a web.
Adambulacral spines usually 3, sometimes 4, short, scarcely projecting beyond web . . . . *rugatus.*
Adambulacral spines 3–5, usually 4, projecting far beyond web.
$R = 1.75\ r\pm$; dorsal membrane thin, evidently reticulated *semireticulatus.*
$R = 1.4\ r\pm$; dorsal membrane thick, not at all reticulate . . *ingoufi.*

Echinaster eridanella.

Müller & Troschel, 1842. Sys. Ast., p. 24.

1 specimen, with six rays, 110 mm. in diameter. Very deep crimson-red in life. Manokwari, New Guinea. — 1 specimen, with six rays, 60 mm, in diameter. Red in life. Makassar, South Celebes. Barbour collection.

Asterias rollestoni.

Bell, 1881. Proc. Zoöl. Soc. London, p. 514.

1 young specimen, 50 mm. in diameter. Nearly white, more or less mottled with deep gray abactinally. Tokyo Bay, Japan, five fathoms. Owston collection.

Although this specimen does not correspond perfectly to either Bell's or Döderlein's (Zool. Anz., **25**, p. 333) description, I think there can be little doubt that it belongs to this species.

Asterias similispinis, sp. nov.

Rays 5. R = 25 mm., r = 5 mm., R = 5 r. Interbrachial arcs acute. Rays little flattened, upper surface somewhat convex, sides scarcely vertical, and actinal surface not sharply marked off. Breadth of ray at base 5.5 mm. Disc moderate; vertical diameter 5 mm. Whole abactinal surface quite closely and very irregularly covered with low stout spines, which though blunt are not capitate; there are three or four of these spines to each square millimeter; a median radial line is seldom well marked. Papular areas very variable in size, with from one to five papulae each. Among the spines are scattered small, rather stout and blunt (less commonly, acute) pedicellariae. On sides of ray can be distinguished a dorso-marginal and a ventro-marginal series of spines; space between these distinct but narrow; dorso-marginal series consists of a single (occasionally double near base of ray) longitudinal row of spines similar to and only a little larger than those on abactinal surface; ventro-marginal series made up of two rows which are quite separate at base of ray but become very closely appressed as tip of ray is approached, the lower spine of each pair being placed aboral to the upper; these spines are little longer than those of the dorso-marginal series, are nearly cylindrical, and blunt; near base of ray there may be two spines placed side by side on each infero-marginal plate, in the lower row of the ventro-marginal series. Most of the marginal spines of both series have a group of small pedicellariae at the base, which, however, do not form a surrounding wreath. Adambulacral armature consists of one or two large blunt cylindrical spines, very similar in appearance to the marginals; near base of ray every other plate bears two spines, the outer one nearer the mouth, but at middle of ray and beyond, most of the plates carry only a single spine; all of the adambulacral spines carry small pedicellariae, and there are similar pedicellariae on the plates within the ambulacral groove. There are no spines between the ventro-marginals and the adambulacrals, but no bare space is visible there, as the entire actinal surface is covered by those spines. Oral plates each with two marginal spines at the inner end, the innermost decidedly the larger; a still larger superoral spine is present on the surface of the plate near the middle. Madrepore plate free from spines, small, 1.5 mm. in diameter, situated about half-way between margin and centre of disc. — Color entirely bleached by alcohol.

6 specimens, 23–45 mm. in diameter. Taraku Island, near Nemuro, Hokkaido, Japan. Owston collection.

It is only with the greatest hesitation that I venture to describe a new Asterias, in the face of the large number of imperfectly described or little known species which now make that genus a source of so much difficulty. But as the six specimens before me agree in all essentials and differ in important particulars from any of the species known to me, and most decidedly from any of the species hitherto known from Japan (see Döderlein's key to the Japanese species of Asterias, Zool. Anz., **25**, p. 331), I have felt justified in giving them a new name, based on the remarkable similarity between the adambulacral and marginal spines.

Although the reproductive organs are fairly well developed, I do not feel confident that these specimens are full grown.

OPHIUROIDEA.

Pectinura gorgonia.

Ophiarachna gorgonia Müller & Troschel, 1842. Sys. Ast., p. 105.
Pectinura gorgonia Lütken, 1869. Add. Hist. Oph., pt. 3, p. 33.

4 specimens. Diameter of disc, 10–11 mm. Green above, more or less blotched with yellowish white; arms conspicuously banded with same colors (dry). Sorong, New Guinea. Barbour collection.

Pectinura infernalis.

Ophiarachna infernalis Müller & Troschel, 1842. Sys. Ast., p. 105.
Pectinura infernalis Lütken, 1869. Add. Hist. Oph., pt. 3, p. 33.

34 specimens. Diameter of disc, 7–11 mm. Light gray to yellow-brown above, more or less variegated; arms distinctly banded with light and dark gray (dry). Sorong, New Guinea. Barbour collection.

Ophiolepis annulosa.

Ophiura annulosa de Blainville, 1834. Man. d'Act., p. 244.
Ophiolepis annulosa Müller & Troschel, 1840. Arch. f. Naturg., **6** (1), p. 328.

3 specimens. Diameter of disc, 15–18 mm. Deep purplish brown above, with large spot at centre of disc, one equally large at base of each arm, and from five to eight bands on each arm, dark buff (dry). Sorong, New Guinea. Barbour collection.

Ophiolepis cincta.

Müller & Troschel, 1842. Sys. Ast., p. 90.

2 specimens. Diameter of disc, 10 mm. Dull olive or brownish above; one specimen with arms indistinctly banded with lighter (dry). Amboina. Barbour collection.

Ophioplocus imbricatus.

Ophiolepis imbricata Müller & Troschel, 1842. Sys. Ast., p. 93.
Ophioplocus imbricatus Lyman, 1865. Illust. Catal., p. 69.

1 specimen. Diameter of disc, 14 mm. Dull brownish above on disc; light olive, with nine or ten narrow dark bands on arms. Amboina. Barbour collection.

Ophiozona longispina, sp. nov.

Diameter of disc, 7–10 mm.; length of arm, 15–25 mm. Disc flat, covered by about 60–75 plates, among which the central dorsal plate, the five radial primary plates, and ten radial shields are conspicuous. Radial shields oval, much larger than centro-dorsal, distinctly longer than wide, separated from each other by a longitudinal series of three or four radial plates. (Relative size and arrangement of other dorsal plates decidedly variable.) — Dorsal arm-plates more or less diamond-shape, two outer sides shorter than inner, with angles rounded (especially distal) or proximal truncate; first three or more (even out to the seventh sometimes) distinctly in contact. — Ventral surface of disc with interbrachial spaces covered by 15–25 plates. Oral shields large (about 1 mm. each way), pentagonal, with an inner angle, and outer side curved; lateral sides nearly as long as inner. Adoral plates somewhat variable, approximately quadrilateral but either broad or narrow; distinctly in contact within. Genital plates moderately large and plainly visible. Oral papillae four on each side, variable in relative size. No "infra-dental" papilla. — Ventral arm plates more or less quadrilateral, at least at base of arm, but becoming indistinctly pentagonal, hexagonal, or even heptagonal further out; first three or four wider than long, fourth or fifth about as long as wide, remainder rapidly becoming much longer than wide: first 4–8 distinctly in contact. — Side arm-plates rather small, coming in contact with each other dorsally at from fourth to eighth arm-joint and ventrally at from fifth to ninth joint; each one carries two (rarely three) long, slender, acute, well-spaced spines, which are usually longer than arm-joint and near base of arm, upper spine, which is longer than lower, may equal two arm-joints. — Tentacle-scale single, of moderate size. — Color (in alcohol) nearly white.

3 specimens. Uraga Channel, Gulf of Tokyo, Japan; 70 fathoms. Owston collection.

List of the species of Ophiozona.

pacifica Lütken, 1856. Vid. Med., p. 22. Pacific Ocean, off Mexico and Central America, littoral.

impressa Lütken, 1859. Add. Hist. Oph., pt. 2, p. 101. Atlantic Ocean off Florida, West Indies, and Brazil, 0–300 fathoms.

nivea Lyman, 1875. Illust. Catal., **8**, p. 9. Atlantic Ocean, off Florida and West Indies, 56–424 fathoms.

antillarum Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 127. Atlantic Ocean, off West Indies, 450 fathoms.

depressa Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 128. Pacific Ocean, off Meangis Islands, 500 fathoms.

dubia Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 224. Atlantic Ocean, off West Indies, 539 fathoms.

insularia Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 126. Pacific Ocean, off Fiji Islands. 310 fathoms.

stellata Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 125. Pacific Ocean, off New Zealand, 700–1100 fathoms.
tessellata Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 223. Atlantic Ocean, off West Indies, 242 fathoms.
clypeata Lyman, 1883. Bull. Mus. Comp. Zoöl., **10**, p. 234. Atlantic Ocean, off West Indies, 151–232 fathoms.
marmorea Lyman, 1883. Bull. Mus. Comp. Zoöl. **10**, p. 233. Atlantic Ocean, off West Indies, 114–250 fathoms.
bispinosa Koehler, 1897. Ann. Sci. Nat., (8) **4**, p. 319. Indian Ocean, off Andaman Islands, 112 fathoms.
alba Lütken & Mortensen, 1899. Mem. Mus. Comp. Zoöl., **23**, p. 102. Pacific Ocean, off Cocos and Galapagos Islands, 770–1360 fathoms.
contigua Lütken & Mortensen, 1899. Mem. Mus. Comp. Zoöl., **23**, p. 101. Pacific Ocean, off Galapagos Islands, 1322–1360 fathoms.
inermis Bell, 1902. Rep. Nat. Hist. "Southern Cross," p. 217. Antarctic Ocean, off Cape Adare, South Victoria Land, 26 fathoms.
casta Koehler, 1904. Oph. Exp. "Siboga," pt. 1, p. 22. Arafura Sea, 312 fathoms.
molesta Koehler, 1904. Oph. Exp. "Siboga," pt. 1, p. 23. Sulu Sea, 705 fathoms; Atlantic Ocean, near Canary Islands, 1175 fathoms.
capensis Bell, 1905. Mar. Inv. South Africa, **3**, p. 256. Indian Ocean, off Cape Colony, 25–900 fathoms.
projecta Koehler, 1905. Oph. Exp. "Siboga," pt. 2, p. 19. Banda Sea, etc., among Dutch East Indies, 8–63 fathoms.
sincera Koehler, 1906. Mém. Soc. Zoöl. France, **19**, p. 12. Atlantic Ocean, off Spain, 679–889 fathoms.
longispina Clark, supra.

Key to the species of Ophiozona.

Tentacle pores not restricted to base of arm; tentacle scales present at least at base of arm.
  Tentacle scales present on all tentacle pores.
    Tentacle scales 2
      Arm-spines 2.
        Arm-spines short, equal; radial shields small, separate or touching *molesta.*
        Arm-spines as long as side arm-plates, upper longer; radial shields large, separate . . . . *bispinosa.*
      Arm-spines 3–5.
        Surface of disc smooth.
          Disk high but flat, margin raised above arms, with a short spine or knob at outer end of each radial shield . . . . *tessellata.*
          Disc-margin raised little, or not at all, above arms; no spine or knob at outer ends of radial shields.
            Oral shields very small, little or not at all larger than one of the swollen adoral plates; arms short, 3–4 times diameter of disc *marmorea.*

Oral shields normal; arms 4–6 times diameter of disc.
Arms about 4 times diameter of disc; lower interbrachial space with less than 30 plates . . . . *nivea.*
Arms about 6 times diameter of disc; lower interbrachial space with more than 50 plates . . . . *clypeata.*
Surface of disc lumpy and irregular, due to numerous, more or less swollen, small plates.
Arms 3 or 4 times diameter of disc; arm-spines nearly or quite equal to joint, rather stout . . . . *impressa.*
Arms 4 or 5 times diameter of disc; arm-spines minute, about half as long as joint . . . . *pacifica.*
Tentacle scale single, though the basal pores may have an extra small scale on the inner side.
Arm-spines 4 . . . . *insularia.*
Arm-spines 2–3.
First side arm-plates of adjacent arms meeting in interbrachial space *dubia.*
First side arm-plates not meeting.
Arm-spines short and peg-like, not exceeding half the arm-joint.
Radial shields well separated.
Most of the disc plates with one or more small but conspicuous tubercles . . . . *projecta.*
Disc plates without tubercles or at most only a single large low tubercle on some of the primary plates.
Upper arm-spine much the shorter; radial shield smaller than central primary plate . . . . *stellata.*
Upper arm-spine the longer; radial shield larger than central primary plate . . . . *depressa.*
Radial shields more or less in contact, or rarely slightly separated.
Arm-spines 3 equal; mouth shield wide, touching first side arm-plate on each side . . . . *casta.*
Arm spines 2, lower longer; mouth shield longer than wide, not in contact with first side arm-plate . . . . *sincera.*
Arm-spines two-thirds as long as arm-joint or longer, radial shields separated.
Side arm-plates meeting above, beyond first upper arm-plate *antillarum.*
Side arm-plates not meeting above, before third upper arm-plate at least.
Side arm-plates entirely separate above, at least on basal half of arm; radial shields small, about as broad as long; upper arm-spine not longer than lower . . . . *contigua.*
Side arm-plates meeting beyond third to eighth upper arm-plate; radial shields large, longer than wide; upper arm-spine the longer.
Basal under arm-plates longer than wide; arm spine not exceeding joint; mouth shield scarcely pentagonal, lateral sides much shorter than inner . . . . *alba.*

3 or 4 basal under arm-plates wider than long; upper arm-spine exceeding joint; mouth shield pentagonal, lateral sides nearly equal to inner . . . . *longispina.*
Tentacle scales wanting on all except basal pores, where there are 2; arm-spines 3, short and peg-like . . . . *inermis.*
Tentacle pores restricted to 3 basal joints of arm; no tentacle scales present; 3 minute arm-spines . . . . *capensis.*

Ophioglypha sterea, sp. nov.

Diameter of disc 7–8.5 mm.; length of arm 15–20 mm. Disc flat but high (vertical diameter about 2 mm.), covered by rather more than 100 plates, among which the centro-dorsal is conspicuous; relative size and arrangement of dorsal plates variable. Radial shields small, not much larger than centro-dorsal, about as wide as long, broadly in contact; inner ends separated very slightly by a radial plate, outer ends distinctly separated by first upper arm-plate. — Arms high and compressed at base, becoming nearly cylindrical towards tip. First upper arm-plate nearly pentagonal with an angle between radial shields, about half as large as one of them; second plate quadrilateral, about twice as wide as long; these two plates are included in the disc notch; third plate quadrilateral with rounded corners, two or three times as wide as long; next three or four plates more or less hexagonal but wider than long and broadly in contact with each other; succeeding plates longer than wide, gradually becoming diamond-shaped with distal angle rounded; somewhere between fifteenth and twentieth arm-joint, these dorsal plates cease to be in contact with each other. — Upper ends of genital plates conspicuous dorsally on each side of base of arm, rounded, flattened, and as wide as second dorsal arm-plate plus half of first; each plate bears an "arm-comb" of about a dozen spinelets, which are minute, flat, and truncate ventrally, but become longer, cylindrical, and acute dorsally; beneath this comb (and naturally concealed by it) on margin of side arm-plate is a delicate fringe of much more minute spinelets. — Ventral surface of disc with each interbrachial space covered by oral shield and about a dozen small plates. Oral shields very large (about 2 mm. long by 1.5 mm. wide), oval with narrow end inwards. Adoral plates very small, with parallel sides. Oral plates larger than adoral, somewhat swollen at inner end, and so forming a slight projection where they meet. Oral papillae four or five on each side; outermost widest and very flat, next two or three short and blunt, innermost longer and pointed; at apex of jaw is an unpaired, pointed papilla, the longest of all. — First ventral arm-plate nearly triangular with base and outer angle rounded; next three or four plates a trifle larger, more nearly square and broadly in contact; next five or six are longer than wide, more or less octagonal, and still in contact with each other; succeeding plates are hexagonal, pentagonal, and finally nearly circular, and are widely separated from each other. — Side arm-plates large; high, broad, and flat near base of arm where they meet neither above nor below; they meet each other dorsally somewhere after the fifteenth joint and ventrally two or three joints sooner.

Each one carries four minute, well-spaced, pointed spines, about one-third as long as plate, nearly equal or uppermost shortest.— Tentacle pores conspicuous, first six or eight with scales on both sides, but further out tentacle-scales are confined to margin of side arm-plates and resemble so closely the arm-spines that it is not easy to distinguish between them; first pore entirely distinct from mouth-slit, with five scales on outer side and five on inner; second pore has six scales on outer (proximal) side and four on inner; third has six and four respectively; fourth, seven and four; fifth, seven and three; tenth, sixth and none. — Color in alcohol white.

4 specimens, Uraga Channel, near Tokyo, Japan. 70 fathoms. Owston collection.

When Lyman published his key to Ophioglypha (Challenger Report, 1882), he included 58 species as valid. Since then more than 40 additional species have been described, chiefly from the collections of the "Siboga," "Albatross," "Blake," and "Investigator," so that it is with some hesitation that I add another to this already unwieldy group. The genus, however, is not so homogeneous but that it can be separated into subordinate divisions which at some future time it may be desirable to recognize as genera. One of these groups, of which *O. variabilis* Lyman is a good representative, has the following characters: —

Disc and arms high, latter rounded, with very short spines; basal under arm-plates about as broad as long; side arm-plates not meeting below within disc; oral shield large and conspicuous, covering a considerable part (sometimes nearly all) of ventral interbrachial space; adoral plates (usually small) at inner point of oral shield; first pair of tentacle pores not opening into mouth-slit; tentacle scales usually numerous. The following species belong in this group: —

bullata Wyville Thomson. 1873. Nature, **8**, p. 400. South Atlantic Ocean, 1240–2850 fathoms.

convexa Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 84. North Pacific, 2050–2350 fathoms (tropical Atlantic, 114–270 fathoms ?).

sculptilis Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 84. Pacific Ocean, off Japan, 1875 fathoms.

variabilis Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 85. Dutch East Indies, 1425 fathoms (West Indies, 175–955 fathoms).

ornata Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 86. Tropical Pacific, north of Dutch New Guinea, 2000 fathoms.

lacazei Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 87. South Pacific Ocean, south of Australia; coast of Chili, 2160–2600 fathoms.

lienosa Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 88. Antarctic Ocean, southwest of Australia, 1950 fathoms.

radiata Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 89. Pacific Ocean, off west coast of Luzon, Philippine Islands, 1050 fathoms.

undata Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 90. Pacific Ocean, west of Fiji Islands, 1450 fathoms.

lapidaria Lyman, 1878. Bull. Mus. Comp. Zoöl, **5**, p. 90. Pacific Ocean, off Japan, 565 fathoms.

fasciculata Lyman, 1883. Bull. Mus. Comp. Zoöl., **10**, p. 237. Atlantic Ocean, off Barbados, 288 fathoms.

saurura Verrill, 1894. Proc. U. S. Nat. Mus., **17**, p. 288. Atlantic Ocean, off northeast coast of United States, 471–677 fathoms.

obtecta Lütken & Mortensen, 1899. Mem. Mus. Comp. Zoöl., **23**, p. 119. Pacific Ocean, between Panama and Galapagos; vicinity of Galapagos Islands, 1201–1360 fathoms.

sterea Clark, supra.

Key to variabilis group of Ophioglypha.[1]

Arm-spines 2 or 3 (rarely 4 near base of arm).
- Radial shields in contact for more or less of their length.[2]
  - Arm-comb present; basal upper arm-plates not ridged.
    - Lower arm-plates separated by side arm-plates, beyond third joint.
      - Arm-spines only 2 . . . . *radiata.*
      - Arm-spines more than 2.
        - Radial shield clearly longer than broad; interradial margin of disc not nearly filled by a single plate . . . . *obtecta.*
        - Radial shield about as wide as long; interradial margin of disc filled by a single plate . . . . *ornata.*
    - Lower arm-plates in contact at least to sixth joint.
      - Primary plates, radial shield, and two large plates in each interradius practically covering disc; oral shield very large, covering nearly entire interbrachial space beneath . . . . *convexa.*
      - Disc covered by more than 100 plates; oral shield covering about two-thirds of the interbrachial space . . . . *lacazei.*
  - Arm-comb wanting; basal upper arm-plates transversely ridged . . *saurura.*
- Radial shields completely separated by small plates.
  - Primary plates large; a single big interradial marginal plate . . . *bullata.*
  - Primary plates small; no large interradial plate on margin . . . . *lienosa.*

Arm-spines 4 or more; radial plates more or less in contact.
- Arm-spines 4 or 5.

[1] The species *abdita* Koehler, 1901, and *mundata* Koehler, 1906, very possibly belong in this group, but Koehler does not say whether the first pair of tentacle pores opens into the mouth-slit or not, and I am unable to satisfy myself on this point from the figures. Another species (*insolita* Koehler, 1904) I should certainly have placed here, judging from Koehler's description and figure, but Koehler himself places it in the group in which the first tentacle pores open into the mouth-slit; I cannot reconcile his figure with such a grouping.

[2] The figure of *O. lacazei* given by Lyman in the "Challenger" Report (Plate 6, fig. 5) shows the radial shields widely separated, in direct contradiction to the earlier figure (Bull. Mus. Comp. Zoöl., **5**, Plate 3, fig. 59) and to both of Lyman's descriptions.

Under arm-plates separated beyond third or fourth.
Basal upper arm-plates broadly in contact . . . . *variabilis.*
Basal upper arm-plates separated beyond second . . . . *undata.*
Under arm-plates not separated until at least the sixth.[1]
Disc covered chiefly by 6 primary plates, 10 radial shields, and 5 large interradials; a large interradial plate just outside oral shield ventrally *fasciculata.*
Disc covered by numerous small plates, among which primary plates are not conspicuous; no large interradial plate outside oral shield *sterea.*
Arm-spines 6 (rarely 5 ?) or more.
Arm-spines not more than 7 . . . . *sculptilis.*
Arm-spines not less than 9 . . . . *lapidaria.*

Ophiocoma brevipes.

Peters, 1852. Arch. f. Naturg., **18** (1), p. 85.

6 specimens. Diameter of disc, 9–17 mm. Color of disk yellowish-brown, with more or fewer dark spots; arms variegated olive and yellowish with narrow dark cross-bands. Amboina. — 3 specimens. Diameter of disc 10–12 mm. Color of disc variegated light and dark brown; arms as in Amboina specimens. Sorong, New Guinea. Barbour collection.

Ophiocoma erinaceus.

Müller & Troschel, 1842. Sys. Ast., p. 98.

1 specimen. Diameter of disc, 8 mm. Color above and below deep purplish-brown, the spines strongly tinged with red. Amboina. Barbour collection.

This specimen is so easily distinguished from the other Ophiocomas in the collection that I am loath to accept the view held by Koehler and others that *erinaceus* is only a variety of *scolopendrina.*

Ophiocoma schoenleinii.

Müller & Troschel, 1842. Sys. Ast., p. 99.

3 specimens. Diameter of disc, 9–15 mm. Color above and below deep purplish-brown, almost black; proximal margin of under arm-plates whitish; as tip of arm is approached, the light color becomes more extensive, especially laterally, passing up on the side arm-plates to the upper surface, until at the extreme tip the arm is prettily banded with white and brown. This peculiar type of coloration is occasionally seen in specimens of *erinaceus.* Amboina. Barbour collection.

[1] Lyman says in his description of *fasciculata*, side arm-plates "meeting neither above nor below," but his figure shows them apparently in contact beyond the sixth under arm-plate.

The re-discovery of this lost species, which Lyman was inclined to regard as identical with *O. wendtii*, while he held both to be of doubtful validity, is a matter of real interest. Koehler (1905, "Siboga" Oph., pt. 2, p. 63; 1907, Bull. Sci. France et Belg., **41**, p. 327) has ably defended the validity of *wendtii*, while the specimens which Mr. Barbour has brought from Amboina show that *schoenleinii* is equally recognizable. It may be distinguished at once from *erinaceus*, which it superficially resembles closely, by the presence of a single large tentacle scale on all the arm-joints beyond the disc; there are usually two on the first arm-joint, sometimes on one side of the second, and very rarely on one side of the third or fourth. The arm-spines are shorter and the oral shields a trifle wider than in specimens of *erinaceus* of the same size. The color also appears to be darker and without any trace of reddish. From *wendtii*, these specimens are easily separated by the short, broad oral shields, nearly as wide at the inner as at the outer end, by the basal under arm-plates which are wider than long, and by the absence of long club-shaped dorsal arm-spines on every third or fourth joint; the color also appears to be a deeper, more blackish brown, and more uniformly dark on the arms. In spite of the fact that it seems to be not only possible but quite easy to divide our Museum specimens of Ophiocoma from the East Indies into these various species, I shall not be surprised if more extended observations, carried on at the shore, prove that *erinaceus*, *schoenleinii*, *scolopendrina*, and *wendtii* are merely intergrading forms of a single variable species.

Ophiocoma scolopendrina.

Ophiura scolopendrina Lamarck, 1816. Anim. s. Vert., **2**, p. 544.
Ophiocoma scolopendrina Agassiz, 1835. Mém. Soc. Sci. Neuchâtel, **1**, p. 192.

47 specimens. Diameter of disc, 6–22 mm. Color dorsally very variable, ranging from uniform deep purplish brown to light yellowish brown, more or less marked with darker and on the arms finely spotted with white; but on the ventral side the under arm-plates and oral shields are always more or less clear yellowish. Sorong, New Guinea. — 3 specimens, similar to above. Amboina. Barbour collection.

Ophiarthrum elegans.

Peters, 1851. Monats. K. Akad. Berlin, p. 464.

1 specimen. Diameter of disc, 12 mm. Color: centre of disc nearly black; margin of disc, arms, and interbrachial spaces yellowish or whitish finely spotted with brown; indistinct cross-bands of brown occur on the arms, especially near tip. Sorong, New Guinea. Barbour collection.

Ophiomastix annulosa.

Ophiura annulosa Lamarck, 1816. Anim. s. Vert., **2**, p. 543.
Ophiomastix annulosa Müller & Troschel, 1842. Sys. Ast., p. 107.

8 specimens. Diameter of disc, 12–26 mm. Color brown, beautifully marked with yellowish white, each upper arm-plate sharply outlined therewith; spines whitish, spotted, or ringed with blackish. Amboina. Barbour collection.

Ophiarachna incrassata.

Ophiura incrassata Lamarck, 1816. Anim. s. Vert., **2**, p. 542.
Ophiarachna incrassata Müller & Troschel, 1842. Sys. Ast., p. 104.

1 specimen. Diameter of disc, 24 mm. Color: disc greenish, centre, and areas over radial shields, light brownish (*not* in marked contrast) spotted with yellow; arms reddish buff; arm-spines light yellow, each with from two to four rings of brownish red; oral shields reddish buff, each with a round yellow spot. Amboina. Barbour collection.

This very handsome specimen, though dry, is nearly perfect. It is of interest because the color agrees fairly well with Müller and Troschel's original description, whereas the "Siboga" specimens seem to have been deep green; at least Koehler says (1905, Oph. "Siboga," pt. 2, p. 65) that Herklot's (1868) colored figure, which is very rich green, variegated on the disc with whitish, is "suffisamment exact."

Ophiothrix longipeda.

Ophiura longipeda Lamark, 1816. Anim. s. Vert., **2**, p. 544.
Ophiothrix longipeda Müller & Troschel, 1842. Sys. Ast., p. 113.

2 specimens. Diameter of disc, 15 mm. Color purple variegated with whitish; spines and spinelets white or nearly colorless. Amboina. — 2 specimens. Diameter of disc 12 mm. Color similar to those from Amboina but lighter. Sorong, New Guinea. Barbour collection.

Ophiocreas papillatus, sp. nov.

Diameter of disc, 15 mm.; length of arm, about 250 mm.; width of arm at base, 4 mm.; height of arm at base, 4 mm. Disc flattened, not higher than arms, concave at centre, covered by a thin skin, which is thickly dotted in radial areas and near margin with minute roundish calcareous granules; of these there are, where thickest, about 75 to a square millimeter. Radial shields long, narrow, and flattened especially towards centre, where they approximately meet; no two are elsewhere in contact. They appear to be made up of several thin, flat, superposed, overlapping plates. Extending from outer end of radial shield at right angles to it, on margin of disc, is a small but very distinct plate, about a millimeter long; it appears to limit upper border of genital slit. Arms approximately cylindrical but flattened ventrally, tapering very gradually, not at all enlarged at base. No upper arm-plates. Skin at base of arm thickly sprinkled with minute calcareous granules like those on disc. Genital plates nearly as large, but not so long, as radial shields; genital slits 4 mm. long, nearly vertical, and parallel. Oral shield wholly invisible. Adoral plates large but indistinctly outlined. Oral plates two, projecting and rather conspicuous. Oral papillae small, rounded, of unequal size, very variable, from five to nine on each side of mouth-slit, situated

far up on sides of slit. Teeth papillae four to six, first or second much larger and more acute than others. Teeth few, apparently only five or six, thick, rounded triangular. — Ventral arm-plates small, separated by rather stout side arm-plates which meet in midline. Tentacle pores very large, diameter equal to or exceeding distance between two consecutive pores; buccal pair without scales but surrounded by a sprinkling of minute granules; first pair on arm much smaller than others and with no tentacle scale; second pair with one tentacle scale; succeeding pores each with a pair of scales. Tentacle scales tapering, rather acute, and more or less spinulose at tip; outer one somewhat shorter than inner, but difference between them is not great on any part of arm; inner one, where longest, is not equal to two arm-joints. Above outer tentacle scale, on each side of every joint until nearly at tip of arm, is a low, rounded tubercle. — Color pale reddish.

1 specimen (dry). Sea of Idzu, Hondo, Japan. Owston collection.

In the large size of the tentacle pores as well as in general appearance, this species is very similar to *O. japonicus* Koehler, but the presence of oral papillae and of granules on the disc, as well as the short nearly parallel genital slits, are such important differences that it does not seem possible that the two can be identical. It must be granted, however, that specific differences in the genus are very slight, and it is by no means certain that the species now recognized are all valid. It seems to be useless to lay any stress on relative proportions of disc and arms, for, as Lyman long ago pointed out, these vary greatly with age. Moreover, the enlargement at the base of the arm, supposed to be characteristic of *oedipus*, appears to be essentially dependent on the condition of the reproductive organs and therefore of very uncertain value. Bearing these facts in mind, I have prepared the following list of, and key to, the species of Ophiocreas. The key shows not only the relationships of the new form herein described, but reveals the remarkably slight differences by which the various species are distinguished from each other.

List of the species of Ophiocreas.

lumbricus Lyman, 1869. Bull. Mus. Comp. Zoöl., **1**, p. 347. Atlantic Ocean, off West Indies, 60–580 fathoms.

abyssicola Lyman, 1879. Bull. Mus. Comp. Zoöl., **6**, p. 64. Pacific Ocean, east of Japan, 2300 fathoms.

oedipus Lyman, 1879. Bull. Mus. Comp. Zoöl., **6**, p. 65. Pacific Ocean, west of Philippine Islands, 500 fathoms; northwest of Halmaheira, 1108 fathoms; and Atlantic Ocean, off Ascension Island, 420–425 fathoms.

carnosus Lyman, 1879. Bull. Mus. Comp. Zoöl., **6**, p. 63. Pacific Ocean, off west coast of Patagonia, 175 fathoms.

caudatus Lyman, 1879. Bull. Mus. Comp. Zoöl., **6**, p. 64. Pacific Ocean, off Enosima, Japan, 345 fathoms.

spinulosus Lyman, 1883. Bull. Mus. Comp. Zoöl., **10**, p. 281. Atlantic Ocean, off West Indies, 116–288 fathoms.

adhaerens Studer, 1884. Abh. K. Pr. Akad. Wiss. Berlin, p. 54. Indian Ocean, off west Australia, 45 fathoms.

constrictus Farquhar, 1900. Trans. N. Z. Inst., **32**, p. 405. Pacific Ocean, off New Zealand.

sibogae Koehler, 1904. Oph. "Siboga," pt. 1, p. 165. Pacific Ocean, off Halmaheira, Kei and Rotti Islands, Dutch East Indies, 113–605 fathoms.

japonicus Koehler, 1907. Bull. Sci. France et Belg., **41**, p. 346. Pacific Ocean, off Japan.

papillatus Clark, supra.

Key to the species of Ophiocreas.

Radial shields and upper arm-plates free from spines.
- Skin of disc and bases of arms free from numerous pits and pores.
  - Oral shields very small, concealed; arms 5; 1 or 2 tentacle scales present on third and commonly on second pair of pores.[1]
    - Tentacle pores small, their diameter much less than distance between 2 consecutive pores.
      - Radial shield long, narrow, thick; genital slits long, exceeding one-eighth of diameter of disc.
        - First 5 or more (rarely only 4) tentacle pores with only 1 scale or none.
          - Skin thick, soft, and smooth; radial shields long, meeting at centre of disc.
            - Skin very thick, wrinkled; no oral papillae or calcareous granules on mouth angles . . . . *carnosus.*
            - Skin thick and minutely tuberculated; small oral papillae or calcareous granules on sides of mouth angles . . . *caudatus.*
          - Skin thin, provided on disc with minute granules; radial shields short, not quite meeting at centre . . . . *oedipus.*
        - First 2 or 3 (rarely 4) tentacle pores with 1 tentacle scale or none.
          - Oral papillae present, 9 or 10 to each mouth angle; skin of disc with numerous minute calcareous granules . . . . *lumbricus.*
          - Oral papillae wanting; skin of disc perfectly smooth . . . *sibogae.*
      - Radial shields short, broad, thin, and flat; genital slits very short, less than one-tenth the diameter of disc[2] . . . . *abyssicola.*
    - Tentacle pores very large, their diameter about equalling distance between 2 consecutive pores.
      - No oral papillae; skin of disc smooth; genital slits long, converging *japonicus.*
      - 5–9 small rounded oral papillae on each side of mouth-slit; skin of disc and bases of arms rough with numerous small calcareous granules; genital slits short and nearly parallel . . . . *papillatus.*

[1] Not counting the buccal pair.

[2] In both the original description (1879) and the Challenger Report (1882) it is said that the genital slits are "5 mm. long," an obvious misprint for 0.5 mm., as shown both by context and figures.

Oral shields large and conspicuous; arms 5–7; no tentacle scales on first 3 pairs of pores, but 2 on each succeeding pore . . . . *adhaerens.*
Skin of disc and bases of arms with numerous minute pits and pores *constrictus.*
Radial shields and upper arm-plates with more or less numerous spines. *spinulosus.*

ECHINOIDEA.

Cidaris metularia.

Cidarites metularia Lamarck, 1816. Anim. s. Vert., **3**, p. 56.
Cidaris metularia Blainville, 1830. Zoöphytes: Dict. Sci. Nat., **60**, p. 212.

1 specimen, 18 mm. in diameter. Guam, Ladrone Islands. Owston collection.

Phyllacanthus baculosa.

Cidarites baculosa Lamarck, 1816. Anim. s. Vert., **3**, p. 55.
Phyllacanthus baculosa A. Agassiz, 1872. Rev. Ech., pt. 1, p. 150.

4 specimens, 24–38 mm. in diameter. Amboina. Barbour collection.

Goniocidaris biserialis.

Stephanocidaris biserialis Döderlein, 1885. Arch. f. Naturg., **51** (1), p. 79.
Goniocidaris biserialis Döderlein, 1887. Jap. Seeigel, p. 10.

3 specimens, 25–32 mm. in diameter. Uraga Channel, Gulf of Tokyo, Japan, 20–30 fathoms. — 1 specimen, 25 mm. in diameter. Sagami Bay (34° 58′ N. × 138° 45′ E.), Japan, 77 fathoms. Owston collection.

Goniocidaris mikado.

Discocidaris (Cidaris) mikado Döderlein, 1885. Arch. f. Naturg., **51** (1), p. 80.
Goniocidaris mikado Döderlein, 1887. Jap. Seeigel, p. 15.

3 specimens, 20 mm. in diameter. Sagami Bay (34° 58′ N. × 138° 45′ E.), 77 fathoms. Owston collection.

Diadema setosum.

Cidaris diadema var. *β setosa* Leske, 1778. Add. Klein, p. xvii (nomen nudum).
Echinometra setosa Leske, 1778. Add. Klein, p. 36; Plate 37, fig. 1, 2.
Diadema setosa Gray, 1825. Ann. Phil., p. 4.

10 specimens, 33–55 mm. in diameter. Amboina. Barbour collection. — 1 specimen, 15 mm. in diameter. Sagami Bay, Japan, 2 fathoms. Owston collection.

The specimens from Amboina are of special interest because they leave no doubt as to what species of Diadema Rumphius (1705) called *Echinometra setosa.* His specimens were the common Diadema of Amboina, and there can be no question that the specimens brought by Mr. Barbour from the same place are the same species. These ten specimens all agree in having the straight, slender pedicellariae, which Mortensen (1904, Dan. Exp. Siam: Ech., p. 11) has pointed out as characteristic of the commonest Indo-Pacific species of Diadema. Dr. Mortensen follows Lovén (1887, Ech. des. by Linn., p. 124) in attaching Linné's name *saxatilis* to this species, but Lovén's argument seems very weak. It is only by altering Linné's description and entirely ignoring his references to figures and to geographical distribution that his *saxatilis* can be applied to any Diadema, and even if all that were done, it would be absolutely impossible to tell to which of the five species recognized by Mortensen, Linné's name should rightly belong. On the other hand, Leske's figures, combined with Rumphius's good description, leave no doubt that a Diadema is the basis of the name *setosa*, and since the type-locality is definitely stated to be Amboina, examination of specimens from that place is bound to show to what particular Diadema the name should be attached. Of course it is quite possible that two or more species may occur at Amboina, but there is no evidence that such is the case, and even if it should prove to be so, the common species is evidently the one which Rumphius describes. It seems, therefore, beyond doubt that *Diadema saxatile* Mortensen, 1904, is the true *Diadema setosum;* whether Lovén's (1887) *saxatile* is the same appears to be indeterminable, while *saxatilis* Linné is almost certainly not a Diadema at all.

The young Diadema from Japan, in the Owston collection, is a very remarkable looking specimen, and I shall not be surprised if it proves to belong to an undescribed species. It differs from all other young Diademas which I have ever seen, or of which I can find records, in coloration. Instead of the usual black (or brown) and white (or whitish) cross-banded primaries, this specimen has the large spines light green with three or four cross-bands of purple. Unfortunately no large tridentate pedicellariae are to be found, although the specimen is perfectly preserved; presumably none have been developed. There are only eight or nine coronal plates in each column, and the number of primary spines in the ambulacra does not exceed ten in each vertical series. Consequently primary spines are not numerous, and secondaries and miliaries are also noticeably few. The longest spines do not exceed 20 mm. — In view of the fact that only a single specimen of this handsome young Echinoid is available, it seems best to record it under the name of the Diadema which is most likely to occur in Sagami Bay, although none is as yet known from there.

Echinothrix calamaris.

Echinus calamaris Pallas, 1774. Spic. Zool., **1**, fasc. 10, p. 31.
Echinothrix calamaris A. Agassiz, 1872. Rev. Ech., pt. I, p. 119.

2 specimens, 33–57 mm. in diameter. Amboina. Barbour collection.

Asthenosoma owstoni.

Araeosoma owstoni Mortensen, 1904. Ann. Mag. Nat. Hist., (7) **14**, p. 82.
Asthenosoma owstoni A. Agassiz and Clark, 1907. Bull. Mus. Comp. Zoöl., **51**, p. 117.

1 specimen, 160 mm. in diameter. Koajiro, Sagami Bay, Japan. Depth not given. — 1 specimen, 130 mm. in diameter. Yenoshima, Sagami Bay, Japan. Depth not given. Owston collection

Asthenosoma ijimai.

Yoshiwara, 1897. Ann. Zoöl. Jap., **1**, p. 8.

2 specimens, 95–115 mm. in diameter. Sagami Bay, Japan. Depth not given. Owston collection.

Heterocentrotus trigonarius.

Echinus trigonarius Lamarck, 1816. Anim. s. Vert., **3**, p. 51.
Heterocentrotus trigonarius Brandt, 1835. Prod. Anim., p. 66.

6 specimens, 52–76 mm. in long diameter. Djamna, New Guinea. — 1 specimen, 60 mm. in long diameter. Sorong, New Guinea. Barbour collection.

Echinometra mathaei.

Echinus mathaei de Blainville, 1825. Dict. Sci. Nat., **37**, p. 94.
Echinometra mathaei de Blainville, 1830. Dict. Sci. Nat., **60**, p. 206.

14 specimens, 20–37 mm. in long diameter. Amboina. — 6 specimens, 28–38 mm. in long diameter. Sorong, New Guinea. Barbour collection. — 1 specimen, 38 mm. in long diameter. Guam, Ladrone Islands. Owston collection.

Stomopneustes variolaris.

Echinus variolaris Lamarck, 1816. Anim. s. Vert., **3**, p. 47.
Stomopneustes variolaris Agassiz, 1841. Mon. d'Ech.: Obs. Prog. Rec. Hist. Nat. Ech., p. 7.

2 specimens, 45–50 mm. in diameter, remarkable for their deep but distinct green color. Sorong, New Guinea. Barbour collection.

Strongylocentrotus depressus.

Toxocidaris depressa A. Agassiz, 1863. Proc. Acad. Nat. Sci. Phil., p. 356.
Strongylocentrotus depressus A. Agassiz, 1872. Rev. Ech., pt. 1, p. 162.

12 specimens, Yenoshima, Sagami Bay, Japan. — 4 specimens, Yemura, Uraga Gulf, Japan, half a fathom. — 4 specimens, Sagami Bay, Japan. Owston collection.

This series of specimens, ranging in diameter from 14 to 67 mm., shows remarkable diversity in the color of the primary spines, which may be deep purple, purplish red, reddish, or white. All the primaries of any one individual are practically of the same color, consequently the specimens appear at first sight to belong to quite different species. I fail to find any other character, however, associated with this color difference.

Strongylocentrotus pulcherrimus.

Psammechinus pulcherrimus A. Agassiz, 1863. Proc. Acad. Nat. Sci. Phil., p. 357.
Strongylocentrotus pulcherrimus Mortensen, 1903. Ing. Ech., pt. 1, p. 121.

21 specimens, 16–33 mm. in diameter. Sagami Bay (34° 59′ N. × 139° 50′ E.), Japan. — 6 specimens, 25–30 mm. in diameter. Negishi, near Yokohama, Japan. Owston collection.

Strongylocentrotus purpureus.

Toxocidaris purpurea v. Martens, 1866. Arch. f., Naturg., **32** (1), p. 137.

3 specimens, 14–17 mm. in diameter. Yenoshima, Sagami Bay, Japan. — 1 specimen, 47 mm. in diameter. Sagami Bay, Japan. Owston collection.

Temnopleurus hardwickii.

Toreumatica hardwickii Gray, 1855. Proc. Zoöl. Soc. London, p. 39.
Temnopleurus hardwickii A. Agassiz, 1872. Rev. Ech., pt. 1, p. 166.

1 specimen, 42 mm. in diameter. Uraga Channel, Gulf of Tokyo, Japan. Owston collection.

Temnopleurus reynaudi.

Agassiz & Desor, 1846. Ann. Sci. Nat., **6**, p. 360.

1 specimen, 17 mm. in diameter. Sagami Bay, Japan, 30–40 fathoms. Owston collection.

Temnopleurus toreumaticus.

Cidaris toreumatica Leske, 1778. Add. Klein, p. 91.
Temnopleurus toreumaticus Agassiz, 1841. Mon. d'Ech., Obs. Prog. Rec. Hist. Nat. Ech., p. 7.

5 specimens, 46–52 mm. in diameter. Uraga Channel, Gulf of Tokyo, Japan. — 1 specimen, 33 mm. in diameter. Sagami Bay (34° 59′ N. × 139° 50′ E.), Japan. Owston collection.

These specimens show great diversity in the height of the test, the vertical diameter varying from less than .50 to more than .65 of the horizontal diameter.

Salmacis sphaeroides.

Echinus sphaeroides Linné, 1758. Sys. Nat., ed. 10, p. 664.
Salmacis sphaeroides Lovén, 1887. Ech. Linn., p. 69.

2 specimens, 55 and 63 mm. in diameter. Amboina. Barbour collection.

Mespilia globulus.

Echinus globulus Linné, 1758. Sys. Nat., ed. 10, p. 664.
Mespilia globulus Agassiz & Desor, 1846. Ann. Sci. Nat., **6**, p. 358.

5 specimens, about 20 mm. in diameter. Yenoshima, Sagami Bay, Japan. — 1 specimen, 27 mm. in diameter. Aburatsubo, Sagami Bay, Japan. Owston collection.

In the specimen from Aburatsubo the spines are very bright red, in striking contrast to the dark green, bare interambulacral spaces, but in the specimens from Yenoshima the colors are more yellowish and not nearly so bright.

Salmacopsis olivacea.

Döderlein, 1885. Arch. f. Naturg., **51** (1), p. 93.

3 specimens, about 18 mm. in diameter. Sagami Bay (33° 9′ N. × 138° 42′ E.), Japan, 30–40 fathoms. — 2 specimens, about 20 mm. in diameter. Uraga Channel, Gulf of Tokyo, Japan, 40 fathoms. — 1 specimen, 24 mm. in diameter. Uraga Channel, Gulf of Tokyo, Japan, 20–30 fathoms. — 1 specimen, 14 mm. in diameter. Aburatsubo, Sagami Bay, Japan. Owston collection.

The specimen from Aburatsubo is remarkable for the very bright green color of the interambulacra, contrasting sharply with the white ambulacra. The others are all olive-brown with more or less evident traces of greenish but with little contrast between interambulacra and ambulacra; the genital and ocular plates are blackish.

Prionechinus agassizii.

Wood-Mason & Alcock, 1891. Ann. Mag. Nat. Hist., (6) **8**, p. 441.

2 specimens, 4.5 and 9 mm. in diameter. Nearly white but with a pink tinge. Sagami Bay (35° 32′ 14″ N. × 139° 31′ E.), Japan, 400 fathoms. Owston collection.

Toxopneustes pileolus.

Echinus pileolus Lamarck, 1816. Anim. s. Vert., **3**, p. 45.
Toxopneustes pileolus Agassiz, 1841. Mon. d'Ech., Obs. Prog. Rec. Hist. Nat. Ech., p. 7.

4 specimens, 62–114 mm. in diameter. Sagami Bay (35° 2′ N. × 138° 52′ E.), Japan. Owston collection.

Clypeaster japonicus.

Döderlein, 1885. Arch. f. Naturg., **51** (1), p. 100.

2 specimens, 87 and 100 mm. in long diameter. Sagami Bay, Japan. — 1 specimen, 54 mm. in long diameter. Sagami Bay (35° 2′ × N. 138° 50′ E.), Japan, 55 fathoms. — 2 specimens, 15 mm. in long diameter. Misaki, Sagami Bay, Japan. Owston collection.

The young ones from Misaki are too small to show specific characters plainly, but the ventral surface is so concave that I think there is little doubt that they are *japonicus*. The specimen 54 mm. long is very different from the larger adults, but its peculiarities may be due to immaturity. The primary spines are relatively few dorsally, only about one-third to one-half as many per square centimeter as in typical *japonicus* (20–25 as against 50–75), and instead of being greenish-white with a broad reddish or brownish band around the middle, they are glassy white; some, however, do show a faint brown band.

Clypeaster scutiformis.

Echinus scutiformis Gmelin, 1788. Linn. Sys. Nat., p. 3184.
Clypeaster scutiformis Lamarck, 1816. Anim. s. Vert., **3**, p. 14.

1 specimen, a broken, bare test, 23.5 mm. in long diameter. Buleleng, Bali, Dutch East Indies. Barbour collection.

Laganum laganum.

Echinodiscus laganum Leske, 1778. Add. Klein, p. 140.
Lagana laganum de Blainville, 1830. Dict. Sci. Nat., **60**, p. 196.

4 specimens, including 3 bare tests, 24–32 mm. long. Saonek, Waigiou, New Guinea. Barbour collection.

According to our now generally accepted codes, the name *bonani* cannot be retained for this species, as it is one of Klein's (1734) names re-introduced by Agassiz in 1841.

Laganum pellucidum.

Peronella (Laganum) pellucida Döderlein, 1885. Arch. f. Naturg., **51** (1), p. 104.
Laganum pellucidum A. Agassiz & Clark, 1907. Bull. Mus. Comp. Zoöl., **51**, p. 128.

2 specimens, about 22 mm. long. Misaki, Sagami Bay, Japan. Owston collection.

Arachnoides placenta.

Echinus placenta Linné, 1758. Sys. Nat., ed. 10, p. 666.
Arachnoides placenta Agassiz, 1841. Mon. d'Ech. Scut., p. 94.

1 specimen, a broken, bare test. Ampenan, Lombok Island, Dutch East Indies. Barbour collection.

Astriclypeus manni.

Verrill, 1867. Trans. Conn. Acad., **1**, p. 311.

3 specimens, 100–125 mm. in diameter. Sagami Bay, Japan. Owston collection.

Spatangus pallidus sp. nov.

Test broad and flattened; width (47 mm.) nearly equal to length (49 mm.), but height little more than half as much; greatest width just back of abactinal system; greatest height (30 mm.) a trifle further back; at labrum, height only 26 mm. Cordate form of test not conspicuous as anterior ambulacral furrow is shallow, only about 2 mm. deep at ambitus. Anterior petals a trifle sunken, about 15 mm. long by 5 wide; there are about 15 pairs of pores in anterior series, and 18 in posterior. Posterior petals longer (17 mm.) and narrower (4 mm.), scarcely sunken; there are about 18 pairs of pores in anterior series, and 19 in posterior. Posterior end of test truncate, a trifle oblique, with slope downwards and forwards; periproct 8 mm. broad and 6 mm. high, covered by 60–70 plates, of which ten are much larger than others and form an outer marginal ring. Ventral surface of test flat on each side of sternum, but latter conspicuously keeled; keel about 11 mm. broad, 3 mm. high, and extending from labrum backward 27 mm. to a point about 15 mm. from lower margin of periproct, which we may call its posterior end; keel is highest, 9 mm. in front of this posterior end; seen from side, therefore, in natural position of test, keel slopes downward markedly from labrum for 18 mm., then slopes upward slightly for 9 mm., to its posterior end, whence test curves abruptly upward 10 mm., to a point on upper margin of subanal fasciole, about 5 mm. below periproct. Labrum slightly curved, but little projecting, 13 mm. from ambitus in furrow. Actinostome little sunken, about 8 mm. wide by 4 mm. long, covered by 30–40 plates, of which most anterior are largest. Bare ambulacral spaces on each side of sternum, about 6 mm. wide. Remainder of test quite closely covered with tubercles, except around actinostome; most of ventral surface is covered by primary tubercles which, however, pass into secondaries posteriorly, laterally, and on crest of keel. On dorsal surface, primaries few and inconspicuous; there are about fifteen small ones in posterior interradius arranged in half a dozen groups of two or three each; there are about ten slightly larger ones in each lateral interradius; and in each anterior interradius there are from twenty to thirty along margin of furrow, gradually passing into secondaries near ambitus. Sutural lines on dorsal surface, especially posteriorly, are slightly sunken and very distinct. Subanal fasciole consists of a broad band (varying from 1.5 to 2 mm.), enclosing an oblong space with rounded corners, about 13 mm. wide and about 8 mm. high (outside limits of fasciole, therefore, 17 × 12 mm.). Uppermost point of fasciole is about 3 mm. below periproct, while its lowest (or most anterior) point includes posterior end of sternum. — Genital pores 4, close together, practically at centre of dorsal surface. Whole test (except around mouth and on bare ventral ambulacra) thickly

covered with very slender, hair-like spines; secondaries and miliaries 1–3 mm. long and primaries up to 9 or 10 mm. in length; primaries, however, not conspicuously different or sharply distinguishable from secondaries. — Color of test pale purple, almost a grayish lavender, darkest in posterior dorsal interambulacrum and in band of subanal fasciole; spines silvery white.

2 specimens, Sagami Bay (35° 11′ N. × 139° 45′ E.), Japan, 50 fathoms. — 1 specimen, Sagami Bay (35° 3′ N. × 138° 48′ E.), Japan. Owston collection.

List of the species of Spatangus

purpureus O. F. Müller, 1776. Zool. Dan., p. 236. Norway to Azores, and in Mediterranean, 5–458 fathoms.

raschi Lovén, 1869. Öfv. Vet. Akad. Förh. Stockholm, p. 733. Norway to Azores, 100–805 fathoms.

lütkeni A. Agassiz, 1872. Bull. Mus. Comp. Zoöl., **3**, p. 57. Japan, littoral (?)–107 fathoms; Moluccas (Sluiter).

capensis Döderlein, 1905. Zool. Anz., **28**, p. 624. South Africa, 40–280 fathoms.

paucituberculatus A. Agassiz & Clark, 1907. Bull. Mus. Comp. Zoöl., **50**, p. 253. Hawaii, 127–286 fathoms.

altus Mortensen, 1907. "Ingolf" Ech., pt. 2, p. 131. "China Seas."

Key to the species of Spatangus.

Primary tubercles of dorsal side numerous, 150 or more in lateral and posterior interambulacra together.
- Subanal fascioled area more than twice as wide as high with a reëntering angle on upper side . . . . *purpureus.*
- Subanal fascioled area not nearly twice as wide as high, with no reëntering angle.
  - Only 2 pairs of ambulacral pores included within subanal fasciole on each side; anterior petals tapering towards ends, more or less decidedly so proximally.
    - Primary tubercles present in ambulacra between end of petals and ambitus; width of posterior petals less than one-fourth length . . . . . *raschi.*
    - Primary tubercles wanting in ambulacra; width of posterior petals more than one-fourth length . . . . *capensis.*
  - 3 pairs of ambulacral pores included within subanal fasciole on each side; anterior petals broad, not tapering towards ends, even proximally *altus.*

Primary tubercles of dorsal side few, less than 50 in lateral and posterior interambulacra together.
- Lateral ambulacra with two, one, or no primary tubercles; test very broad and flat, vertical diameter about equal to one-half length or less . *paucituberculatus.*
- Lateral ambulacra with from six to twelve primary tubercles; vertical diameter usually more than half the length.
  - Plastron with little or no keel; subanal fasciole 1–1.5 mm. broad; color deep purple . . . . *lütkeni.*
  - Plastron with conspicuous keel; subanal fasciole 1.5–2 mm. broad; color grayish lavender . . . . *pallidus.*

Maretia planulata.

Spatangus planulatus Lamarck, 1816. Anim. s. Vert., **3**, p. 31.
Meretia planulata Gray, 1855. Cat. Rec. Ech. Brit. Mus., p. 48.

3 specimens, about 45 mm. in length; Sagami Bay (35° 10′ N. × 139° 48′ E.), Japan. Owston collection.

Lovenia gregalis?

Alcock, 1893. Journ. Asiat. Soc. Bengal, **62**, p. 175.

1 specimen, 26 mm. long. Sagami Bay (35° 12′ N. × 139° 44′ E.), Japan, 60 fathoms. Owston collection.

Although there can be little question that this young spatangoid is a Lovenia, there is abundant room for doubt as to its being *gregalis*, for the specific characters are not yet evident.

Brissus carinatus.

Spatangus carinatus Lamarck, 1816. Anim. s. Vert., **3**, p. 30.
Brissus carinatus Gray, 1825. Ann. Phil., p. 9.

4 specimens, 56–93 mm. long. Sagami Bay, Japan. Owston collection.

Metalia spatagus.

Echinus spatagus Linné, 1758. Sys. Nat., ed. 10, p. 665 (= E. maculosus Gmel.).
Metalia spatagus Lovén, 1887. Ech. des. Linn., p. 162.

1 specimen, 28 mm. long. Sagami Bay (35° N. × 138° 41′ E.), Japan, 25 fathoms. Owston collection.

Schizaster japonicus.

A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 212.

4 specimens, about 50 mm. long. Sagami Bay (35° 22′ N. × 139° 40′ E.), Japan. — 1 specimen, Sagami Bay (35° 12′ N. × 139° 44′ E.), Japan. — 1 specimen, Uraga Channel, Gulf of Tokyo, Japan, 20–30 fathoms. Owston collection.

All but two of these specimens are badly crushed.

Schizaster ventricosus.

Gray, 1851. Ann. Mag. Nat. Hist., (2) **7**, p. 133.

4 specimens, about 30 mm. long. Sagami Bay, Japan. — 2 specimens, Tokyo Bay, Japan, 10 fathoms. Owston collection.

All but one of these specimens are badly crushed.

HOLOTHURIOIDEA.

Thyone anomala?

Östergren, 1898. Zool. Anz., **21** p. 110.

1 specimen, about 75 mm. long by 13 in diameter. Sagami Bay (35° 3′ N. × 138° 47′ E.), Japan, 110 fathoms. Owston collection.

The specimen is contracted, and having been preserved in formalin, the calcareous particles in the skin are entirely wanting, except a few perforated and somewhat corroded plates in the tentacles. The general anatomy agrees well with *anomala*, except that I found only a single stone-canal. Of course, without the calcareous particles of the skin, actual identification of a Thyone is impossible.

Holothuria monacaria?

Lesson, 1830. Cent. Zool., p. 225.

1 specimen, about 140 mm. long. Okinose, Sagami Bay, Japan. Owston collection.

This specimen is also strongly contracted, and the outer layer of calcareous particles appears to be nearly all dissolved; at least tables are very rare, while buttons with three pairs of holes are exceedingly common. The general appearance of the animal is very much like a Stichopus, for there is a series of large warts along each side and others are scattered over the back, while the ventral surface is thickly covered with pedicels. The deposits, however, seem to agree perfectly in form with those of *monacaria*, and I therefore refer the specimen to that species, although its condition is such as to leave room for doubt.

Molpadia rosacea, sp. nov.

Body stout, 100 mm. long by about 50 mm. in diameter; oral disc 15 mm. in diameter; caudal appendage very small, only 5 mm. long, and apparently without any anal papillae. Skin thin and smooth. Tentacles fifteen, of uniform size; each one is about 4 mm. long and 1 mm. in diameter; nearly a millimeter from the tip on each side is a very slender digit only a quarter of a millimeter long; no other digits are present. No evident genital papilla. Calcareous ring not very stout; radial projections posteriorly rather small and delicate. Polian vessel single. Stone-canal single, spirally wound in dorsal mesentery. Respiratory-trees well developed but slender; right one extending forward so far as to lie against calcareous ring. Calcareous deposits in body wall very scarce, consisting of irregular perforated plates, which have the appearance of having been discs of small tables; they are only 80–100μ across and have from two to six holes; most of them are colored and apparently becoming transformed into phosphatic bodies; these latter are exceedingly abundant but extraordinarily small, scarcely any exceeding 40μ in diameter; they are arranged in small groups which appear as

crowded colored patches on the skin half a millimeter or less in diameter. Although the color of these phosphatic bodies, when seen under the microscope, is yellowish brown with little trace of red, the color of the animal to the unaided eye is decidedly reddish. — Oral disc and caudal appendage very light gray; all other parts densely speckled, especially anteriorly, with minute patches of light dragon's-blood red (Ridgway's Nomenclature of Color); general effect, therefore, is light old-rose red.

1 specimen, Yenoshima, Sagami Bay, Japan. Depth unknown. Owston collection.

It is with no little hesitation that I add another to the already long list of Molpadias described from a single specimen, but I cannot assign this Japanese novelty to any species hitherto described. It is most nearly related to *M. intermedia* of the North Pacific, but is easily distinguished from that species by the absence of tables, the minute phosphatic bodies, and the color. The "Key to the Species of Molpadia," recently published (Smiths. Cont. Knowl., **35**, p. 158), will have to be modified as follows to include *rosacea*.

A. Anchors wanting, etc.
 B. Phosphatic deposits present, etc.
  C. No true supporting rods, etc.
   D. Tables of body often very irregular, distorted or incomplete, sometimes wholly wanting; disc seldom with more than eight holes (those in tail may have 20–30 holes).
    E. Tables with more or less distinct disc, having 2–8 or more (usually 3–6), holes often with irregular outline and marginal projections; sometimes with no spire, and thus reduced to small irregular plates with 2–8 perforations.
     F. Tables or plates of moderate size, 80–350μ in diameter, usually with only one spire.
      G. Tables often wanting in skin of body, present in tail; disc quite asymmetrical; spire of moderate height, etc.

. . . .

      GG. Tables (or perforated disc-like plates) present in skin of body; disc rather symmetrical with 3–6 or more holes; spire (when present) high.
       H. Phosphatic deposits more than 60μ in diameter; tables with spires; color not old-rose red.
        Discs, etc. . . . . *intermedia.*
        Discs, etc. . . . . *andamanensis.*
       HH. Phosphatic deposits very minute, 40μ or less in diameter; tables reduced to perforated disc-like plates; color old-rose red . . . . *rosacea.*
     FF. Tables, etc. *similis.*

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SOME NEW REPTILES AND AMPHIBIANS.

By Thomas Barbour.

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No. 12.— *Some New Reptiles and Amphibians.* By Thomas Barbour.

During 1906 and 1907 I was engaged in zoölogical collecting in India, Burma, and the Dutch East Indies. Collections in various branches of zoölogy were obtained, but special efforts were made to secure reptiles and amphibians in large series. For this reason Java, which is the type locality for a considerable number of forms, was rather extensively investigated. Happily with excellent results, as the time of year, December, 1906, and March and April, 1907, proved very favorable. Large numbers of natives were employed, and much aid was freely given by many of the Dutch officials, to whom thanks and credit will be given in the more detailed account of the collections. Thanks to the energy of Mr. Alan Owston of Yokohama, most excellent Japanese collectors have visited the Riu Kiu Archipelago and Formosa again and again, having provided thus a large part of the material which was used by Stejneger in his Herpetology of Japan and adjacent territory (Bull. 58, U. S. Nat. Mus., 1907). Subsequent Formosan collections have yielded the new species described here. Finally a collection replete in specimens of the highest interest was obtained from Mt. Wuchi in the interior of the island of Hainan. Concerning this region Boulenger wrote (P. Z. S., 1899, p. 956) the following on the receipt of the collections of the late Mr. John Whitehead: "The fact that so many of the few species represented in the collection are new, tends to show how rich a harvest these unexplored mountains would have yielded but for the fatal climate which has deprived the zoölogical world of one of its most enthusiastic and successful members."

Several new forms are here described from unidentified material which has long been in the collection here.

My sincere thanks are due to Dr. Stejneger, who has helped me in a most disinterested and generous way, and to Mr. Garman, whom for many years I have called on freely for advice.

REPTILIA

Goniurosaurus, gen. nov.

Digits moderate; otherwise exactly as in Aelurosaurus. Body covered with excessively small, flat juxtaposed scales and larger tubercle-like scales. Upper and lower eyelids well developed, as in Aelurosaurus (Geckonidae) and in the Eublepharidae. Pupil vertical. Tail elongate with whorls of scales proximally. That the tail is capable of being curled up is evident from its position in the type preserved in alcohol. Possibly this genus should also contain *Pentadactylus brunneus* Cope, which Boulenger placed provisionally in Aelurosaurus.

Goniurosaurus hainanensis, sp. nov.

Habit slender. Head depressed, subtriangular, distinct from neck; snout pointed, distance from anterior border of eye to tip of snout equal to distance from posterior border of eye to ear opening; ear opening a small, narrow, almost vertical slit. Body long, somewhat depressed. Limbs rather long, thin. Scales of top of head, body, limbs, and tail small, uniform flat granules, of varying shapes; among these on the back more or less regular longitudinal series of enlarged tubercular scales occur; these are also scattered over the upper surfaces of the limbs and are present on the proximal half of the tail in twelve whorls, which are not complete below. Scales of all the lower surfaces larger than the contour scales of the upper surfaces, polygonal, subequal. Male with twenty-nine preanal pores in an angular series. Rostral scale one and one-half times as broad as high; separated from the nostril by two enlarged superposed scales, the anterior nasals; the nostril lies behind these, and is surrounded elsewhere by small scales; it is not in contact with a supralabial. There are no other enlarged scales except the supralabials, ten in number, and a few enlarged granules on top of the nose. Mental large, an imperfect equilateral triangle. Tail long, slender, a little shorter than the distance from vent to tip of nose.

Color very dark brown, almost black; limbs brown, belly white. A white band reaching around the back of the head from eye to eye; a white band across body near the fore limbs, one across the middle of the body and one across the body near the hind limbs. Three white rings around the tail, which is almost black above and below. The extreme tip of the tail is white.

Type. — No. 7104, Mus. Comp. Zoöl., a single specimen, taken 16 November, 1906, on Mt. Wuchi, Central Hainan, by a Japanese collector of Mr. Alan Owston.

Glauconia carltoni, sp. nov.

Snout rounded; supraocular present, very small; rostral extending almost to level of eyes; about twice as broad as the nasal, which is completely divided into two; ocular bordering the lip for a considerable distance between two labials, the first of which reaches to the level of the nostril only; five lower labials. Scales

on body in 14 rows. Diameter of body 55 times in the total length, in length of tail 5.5 times; length of tail in that of body about 10.

Color very light brown above, ashy gray beneath.

Type. — No. 3749, Mus. Comp. Zoöl., Amballa, India, M. M. Carlton.

There are two other specimens in the collection, No. 3217, which show the same characters as the type.

The species is named for Rev. M. M. Carlton, who for many years made valuable collections in Upper India.

This new form evidently represents a localized race of *G. blanfordii* Blgr., known first from Sind, the type locality, and later from Northern Beluchistan (Alcock & Finn., Journ. Asiat. Soc., Bengal, **65**, p. 561). Its most noticeable divergence is its less elongate form.

Natrix aequifasciata, sp. nov.

Eye rather large. Rostral broader than deep, just visible from above; internasals almost wedge-shaped, twice as long as broad, one and one-half times as long as prefrontals; frontal one and two-thirds as long as broad, as long as distance from end of the snout, shorter than the parietals; loreal as long as deep; two preoculars and two or three postoculars; one or two suboculars may be present, — these are very small and separated by the fifth upper labial. Temporals 2 + 3, — these may be broken into several scales; nine upper labials, the seventh largest and the fifth always entering orbit, — the fourth and sixth may do so also, or they may be excluded by the suboculars; five pairs of lower labials in contact with anterior chin shields, which are a very little shorter than the posterior. Scales in nineteen rows strongly keeled, except the outer row, on which the carination is weak. Ventrals 148–151; anal divided; subcaudals 74–75.

Color (in alcohol) boldly banded with twenty or twenty-one black bars on the body and twelve on the tail. The interspaces narrower than the bars, but less narrow laterally than dorsally, white with a slight brownish tinge. Ventral surface ivory white, with black markings of the bars; these often end abruptly at the median line. The black blotches are roughly alternate.

Types. — No. 7101, Mus. Comp. Zoöl., two specimens, each about 20 cm. long, from Mt. Wuchi, Central Hainan. Taken by one of Mr. Owston's Japanese collectors.

This strongly differentiated species shows a probable relationship to both *N. tigrina* and *N. piscator.*

Cope's *Trimenodytes balteatus* (Proc. Acad. Nat. Sci. Phila., 1894, p. 426) probably represents an abnormal Natrix, which, however, cannot be identified with this species.

Pseudoxenodon stejnegeri, sp. nov.

Rostral just visible from above; internasals shorter than prefrontals; frontal almost one and one-half times as long as broad, shorter than distance to tip of

snout, much shorter than parietals; loreal as long as deep; two preoculars; three postoculars; temporals 2 + 2; eight upper labials, fourth and fifth entering orbit; five lower labials in contact with the anterior chin shields, which are very nearly the same size as the posterior. Eleven dorsal rows of scales keeled, only the dorsal 5 strongly; scales in nineteen rows anteriorly, in seventeen rows on middle of body, and in fifteen rows near the tail. Ventrals 153; anal divided; subcaudals in 68 pairs.

Color olive above, with an indistinct lateral series of dark blotches; head with a black stripe from posterior border of the orbit to the angle of the jaws; upper labials with sharp black markings along their posterior edges; upper lip yellowish; lower surfaces dull white, confluent dark olive puncticulations form three irregular bands, one along the middle and one on each end of the gastrosteges; there are many scattered spots elsewhere, also larger diffuse brown blotches. On the under surface of the tail the dots are irregularly scattered and produce a gray effect. Along the sides of the tail is a white line formed by spots on the outer end of each subcaudal scale. There are no spots on the throat, which is pure white. Length of body 370 mm.; length of tail 100 mm.

Type. — No. 7103, Mus. Comp. Zoöl., a single specimen, from Mt. Arizan, Central Formosa. Taken 29 November, 1906, by one of Mr. Owston's Japanese collectors.

This species seems to be, as would be naturally expected, related to *P. dorsalis* (Günther) from China. It differs in having two preoculars instead of one, in the number of ventral and subcaudal scales, and in coloration.

It is a privilege to associate with this interesting new species of a genus hitherto unrecorded from Formosa, the name of a kindly friend and generous helper, Dr. Leonhard Stejneger.

Holarchus nesiotis, sp. nov.

Nasal divided; rostral reaching far back above, completely separating the internasals and coming into contact with the prefrontals. Frontal very large, much longer than distance to tip of snout, longer than the parietals. Loreal square; two pre- and two post-oculars; temporals 1 + 2, the lower of the two temporals is the smaller, while the opposite is the condition in *H. formosanus* figured by Stejneger (Herp. of Japan, 1907, p. 355). Eight upper labials on each side, fourth and fifth entering eye; four labials in contact with anterior chin shield, which measure about one and one-third the size of the posterior. Scales in 19 rows, perfectly smooth. Ventrals distinctly angulate, 169; anal divided; subcaudals 56 pairs.

Color pale brown above, with an indistinct light vertebral line and four dorsal and dorso-lateral longitudinal bands of slightly darker brown. Sides and belly ivory white. On the parietals there are dark brown spots, also a symmetrical square brown, almost black, blotch below the eye on supralabials 5 and 6. A chevron-like band on the nape with its apex directed forward.

Type. — No. 7107, Mus. Comp. Zoöl., a single specimen, about 355 mm. long, from Ting-an, Hainan Island. Taken by a collector for Mr. Owston.

Related to *H. formosanus hainanensis* (Boettger), to which form Cope's *H. dolleyanus* (l. c. p. 423) must be considered a synonym. Boettger's paper (Ber. Senck. Nat. Ges. 1893–4) was received at the library of the Mus. Comp. Zoöl. Oct. 16, 1894. Cope's paper did not appear until Feb. 13, 1895.

Calamaria sondaica, sp. nov.

Rostral very nearly as deep as broad, easily visible from above; frontal a little longer than broad, considerably shorter than the parietals, a little more than twice as broad as a supraocular; one pre- and one post-ocular; diameter of the eye a little less than its distance from the mouth; five upper labials, the first nearly three times as large as the second, which is smaller than the third or fourth. These are subequal and enter the eye. The fifth is larger than the third and fourth together. A pair of infralabials in contact between the mental and the anterior pair of chin shields. Scales in 13 rows; ventrals, 154; anal entire; subcaudals 10. Tail rather obtuse. Dark reddish brown above (with fine plumbeous iridescence in life); six dark lines just visible on neck, very indistinct on body; rows of scales separated by zigzag white lines; a lateral white line on last row of scales. Ventral surfaces white (yellow in life), very heavily blotched with angular dark markings; a black line down midventral region of the tail and two black lateral lines on tail.

Type. — No. 7102, Mus. Comp. Zoöl., one specimen Buitenzorg, Java, April, 1907. T. Barbour, collector.

It is with great reluctance that this new species is described. No ophidian genus cries for a revision more than Calamaria. Nevertheless this new form seems to merit recognition on account of several distinctive characters.

Superficially, i. e. in coloration, this form does not bear the slightest resemblance to its nearest relative, which is *C. virgulata;* nor, it may be added, does it seem to agree with any of the forms which Boulenger (Cat. Snakes, 1894, **2**, p. 340), has considered synonymous with this species.

Calamaria albopunctata, sp. nov.

Rostral somewhat broader than deep; frontal longer than broad, much shorter than parietals, and less than twice as broad as a supraocular; one pre- one post-ocular; diameter of eye less than distance to mouth; five upper labials, first, third, and fourth subequal, second and fifth large; third and fourth entering orbit; first infralabial meeting its fellow behind the symphysial; two pairs of chin shields in contact with each other. Scales in 13 rows; ventrals 247; anal entire; subcaudals 14. Tail rather blunt. Dark brown above, a lighter band on occiput; two outer rows of scales with light centres; lower surfaces yellow with a few dusky markings; a blackish line along lower surface of tail.

Type. — No. 7106, Mus. Comp. Zoöl., one specimen from the East Indies.

Several years ago a collection of reptiles was offered for sale which purported to come from the Moluccas and was marked "Ternate or Amboina." Many of the specimens undoubtedly did come from the Moluccas. The Calamaria which is described above, reminds one strongly of *C. occipitalis* Jan, and very possibly will be found locally in some one of the many small areas in Java which are as yet unknown herpetologically. That we do not yet know completely the calamarian fauna of Java is attested by the fact that in April, 1907, at Sindanglaia in Western Java, a specimen of *C. sumatrana* Edeling was taken, thus adding a species to the list, already a long one, of forms known to inhabit Java.

Pseudelaps muelleri insulae, subsp. nov.

Rostral scale visible from above. The eye is somewhat greater in diameter than its distance from the mouth. The scales around the body are in 15 rows; the ventrals 146 and the subcaudals 19 pairs in number. The anal is divided. Total length 400 mm.; tail 32 mm. Boulenger's (Cat. Snakes, 1896, **3**, p. 317), measurements of *P. muelleri* are as follows: "Total length 500 millim; tail 70."

Color. In life this is almost coal black above with rich plumbeous iridescence when held in bright light. The ventral surface is, in general, dusky white. Along each of the gastrosteges runs a line of dark brown spots; these spots occur in a closely grouped cluster at the ends of each ventral scale. In the gular region the spots fuse and grow darker in color; the general effect is a very deep brown. On the lower labials small white spots occur, irregularly scattered. In alcohol, however, the black has changed to a very dark dull green and the brown markings below to an olive color.

Type. — No. 7080, Mus. Comp. Zoöl., one specimen, Djamna Island, Dutch Papua. T. Barbour, collector. Djamna is a small islet, situated off the Saär district between Cape D'Urville and Humboldts bay. It lies a few miles south-east of the Arimoa (Kumamba) group of islands.

This form differs from *Pseudelaps muelleri* (Schlegel) in having a much shorter tail, fewer pairs of subcaudal scales, and a distinctive coloration.

This subspecies may be identical with "*P. schlegelii* (Günther)," which seems distinguishable as a race of *P. muelleri* (Schl.). The color of this Djamna form does not, however, seem within the variation limits of any described form.

AMPHIBIA

Prostherapis equatorialis, sp. nov.

Snout depressed, projecting, rather pointed, truncate with angular canthus rostralis; loreal region slanting inward from below; nostril very close to tip of snout; interorbit very broad, slightly convex; tympanum very small but distinct, about one-third the width of eye. First finger slightly shorter than second; toes free; discs small; subarticular and inner metatarsal tubercles indistinct; no

outer metatarsal tubercle. The hind limb being carried forward along the body the tibio-tarsal articulation reaches the posterior border of the eye. Skin smooth above, tubercular on posterior part of belly and lower surfaces of thighs.

Color rich brown above, striped with darker, a narrow white vertebral line; all lower surfaces whitish. Male with a large subgular vocal sac.

Types. — No. 2261, Mus. Comp. Zoöl., two examples, from Equador.

For the sake of comparison with the above species I append a description of *P. femoralis* Barbour from Gorgona Island off the coast of Colombia.

Snout broad, depressed, with angular canthus rostralis; loreal region nearly vertical; nostril nearer tip of snout than eye; interorbital space somewhat broader than upper eyelid; tympanum indistinct but not quite concealed. First finger longer than second; rudiment of web between third and fourth toes; subarticular tubercles moderate, metatarsal tubercles small. The hind limb being carried forward along the body, the tibio-tarsal articulation reaches well beyond the eye. Skin smooth above and below.

Color gray above with faint brown marblings, below pale gray with rich chocolate markings, which are most abundant on the chin region.

Cacopoides, gen. nov.

An engystomatid related to Cacopus. The precoracoids are wanting, the coracoids meet each other on the median line, without an intercalated cartilage; the large metasternal cartilage, instead of being connected to the coracoids by an isthmus, much more narrow than the metasternum itself, is closely adpressed to the coracoidal symphysis. This may be made more clear by the appended drawings. Choanae small, with valve-like flaps; dermal ridges behind the choanae converging posteriorly and each with an enlarged papilla near the median line; another long ridge in front of the oesophagus which is sharply curved anteriorly near the median line. Tympanum hidden. Fingers free, toes webbed at base, tips not dilated. Sacral diapophyses rather strongly dilated.

Cacopoides borealis, sp. nov.

Habit very stout. Head small; mouth small; snout rounded; no canthus rostralis; snout about as long as orbital diameter; interorbital space more than twice the diameter of the upper eyelid. Fingers moderate, first shorter than second; toes moderate, webbed at base; no subarticular tubercles; two metatarsal tubercles, the inner strong and shovel like, the outer weak. Hind limb short. Skin smooth, the dorsal surface with scattered minute pits. Color dark brown-olive above; beneath dusky, marbled with brown. A subgular vocal sac is present.

Type. — No. 2436, Mus. Comp. Zoöl., one example, from Antung, Manchuria.

Dr. Stejneger has seen this specimen and doubts the correctness of the locality; he has suggested Autung in Kiang hsi. The specimen was, however, taken by a Japanese bird collector of Mr. Owston and from what Mr. Owston states and from

other specimens which were said to come from the same locality I feel that there is very strong circumstantial evidence that the locality is correct. It may possibly have been confused in Mr. Owston's laboratory with material from Hainan or Formosa, but even in this case would be nearly as far from its relatives as it would be in Manchuria.

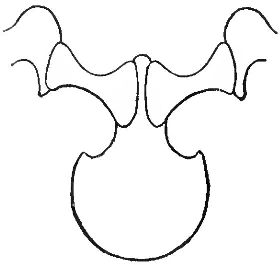

FIG. 1

Cacopus. — Pectoral girdle (after Boulenger).

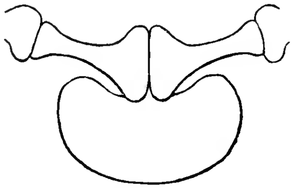

FIG. 2

Cacopoides. — Pectoral girdle.

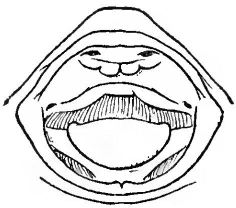

FIG. 3.

Cacopoides borealis. — Interior of mouth.

Microhyla hainanensis, sp. nov.

Habit stout. Snout rather rounded, longer than orbital diameter; interorbital space about equal to upper eyelid. Fingers moderate; first much shorter than second; fourth much the longest; toes moderate, nearly one-half webbed; tips of finger and toes not dilated; subarticular tubercles present, inconspicuous on fingers but very pronounced beneath the toes; two palmar tubercles, the outer by far the larger; two small metatarsal tubercles, the outer the more prominent. The hind limb being carried forward along the body the tibio-tarsal articulation reaches to or beyond the tip of the snout. Skin mostly smooth, with a few scattered tubercles on the posterior part of the back and a larger number on the outer sides of the thighs.

Color olive or pinkish brown in various shades; several chevron-like bands of a darker tone on the back; a dark band between the eyes which may be inter-

rupted on the median line; a dark band along each side and many cross-bars on the limbs; a large very dark brown — almost black — spot on each side of the vent. Throat and sides of chest clouded with dusky brown; the remainder of the lower parts immaculate. Male with a subgular vocal sac.

This form is evidently a near relative of *M. pulchra* (Hallowell), but is easily distinguished by the stout form of body and hind limbs, the scattered tubercles, and the conspicuous black spots.

Types. — No. 2435, Mus. Comp. Zoöl., four specimens from Mt. Wuchi, Central Hainan. Taken by a Japanese collector of Mr. Alan Owston.

Ceratophrys intermedia, sp. nov.

Vomerine teeth in a slightly interrupted series between the choanae; this series is not quite straight as in *C. fryi*, but the two halves point slightly backward on the median line. The first and second fingers are of very nearly the same size, the first slightly longer than the second. The color and granulation of the back is the same as in *C. boiei* except that there is no conspicuous brown spot below the eye; and there is a white band joining the orbits.

Type. — No. 2254, Mus. Comp. Zoöl., from Santa Katharina, Brazil.

This species stands between *C. boiei* Wied, and *C. fryi* Günther.

Bufo bankorensis, sp. nov.

Habit very similar to *B. himalayanus* (Günther) and *B. melanostictus* Schneider. It differs markedly from the former in the smoother crown, in that the warts on the upper surfaces of the body, and especially on the legs, are much smaller, more scattered, and subequal. It differs conspicuously from the second mentioned species in the absence of the cephalic ridges.

Crown deeply concave, smooth; ridges between eye and nostril very weak; snout short and blunt; interorbital space much wider than upper eyelid; tympanum small, vertically oval, partially covered by a fold of skin. First finger a very little longer than second; a small inner and an outer palmar tubercle, which is nearly three times as large as the inner one; subarticular tubercles single, rather prominent. There are many other tubercles on palm and digits. The hind limb being carried forward the tarso-metatarsal articulation reaches beyond the tip of the snout; toes less than half webbed, the webs with their outer edges denticulate; small, single, subarticular tubercles on all but fourth toe, where they are double; two subequal metatarsal tubercles, the inner the more prominent; lower surfaces of feet richly tuberculate like the hands. A slightly developed tarsal fold more conspicuous in the male than in the female. Upper surfaces with subequal warts well separated by areas of smooth skin; in the female specimen the warts show a tendency towards spinosity. The parotoid glands are large, suboval, or tending toward kidney shape. I do not find an internal vocal sac in the male; in this particular especially is the tendency toward

B. himalayanus. In the specimen of this sex nuptial asperities are present on the first and second finger.

Color (in alcohol) dark brown above, lighter below; a blackish band begins at posterior border of eye, covers the lower half of the paratoid gland, and runs along the side, ending in a series of spots. In the female many of the warts have black apices, a character frequent in *B. melanostictus.*

Type. — No. 2432, Mus. Comp. Zoöl., two specimens, a male and female, Bankoro, Central Formosa. Taken by a Japanese collector of Mr. Alan Owston.

This strongly marked species is evidently closely related to *Bufo melanostictus;* it also tends towards *Bufo himalayanus.* This opinion is also held by Dr. Stejneger, who has most kindly examined the types.

Hyla kampeni, sp. nov.

Tongue subcircular, slightly nicked and free behind. Vomerine teeth in two short groups between the middle of the choanae, the interspace separating them as wide as one of the groups. Snout rounded, tympanum round; its diameter is equal to two-thirds of the distance from eye to nostril. Rudiment of pollux present. Fingers webbed as follows: second digit two-thirds, third wholly, fourth almost wholly, fifth wholly. The toes are all wholly included in the extent of the web. Discs large, almost as large as tympanum. Skin smooth above, belly and lower side of thighs finely granulate. Upper surfaces greenish brown (dull green in life), lower surfaces unmarked yellow.

Type. — No. 2433, Mus. Comp. Zoöl., a single specimen, taken at Wahaai, Ceram, January, 1907, by T. Barbour.

Hyla kampeni is nearly related to *H. montana* Peters e Doria. It may be readily distinguished by its larger tympanum, greater extent of webbing between the toes, and a more slender build. It is also evidently different from *H. amboinensis* Horst and H. ruepelli Boettger, which we might expect to find in this locality.

Recently Dr. P. N. van Kampen has produced (Max Weber's Zoologische Ergebnisse einer Reise in Niederländisch Ost-Indien, 1907, **4**, pt. 2, p. 383–418, pl. 16) a most excellent piece of work in which he tabulates the ranges of East Indian Amphibians so far as they are known. He records *Hyla dolichopsis* Cope and *H. vagabunda* Peters e Doria as the only ones hitherto known from the island of Ceram.

This species is named for Dr. van Kampen, friend and companion in travel in the Dutch East Indies.

Van Kampen has shown (Nova Guinea, **5**, Zoölogy, p. 176) in a recent account of New Guinea Amphibians that it is probable that the young of several species of Hyla lack vomerine teeth. Is it not, then, also possible that this may be the case with some adults? Answering this in the affirmative he recommends that Hyla and Hylella be united. He also notes that Gadow (Amphibia and Reptiles, 1901) has remarked that owing to the wide discontinuity of the range of

Hylella it cannot be considered a monophyletic genus. The occurrence of three species of tree-toads lacking vomerine teeth, on the comparatively small island of Jobi, is rather remarkable.

Hyla ouwensii, sp. nov.

Head short; snout squarish; loreal region rather concave; tympanum extremely small, about one-fifth diameter of eye; the tibio-tarsal articulation reaches a considerable distance beyond the snout. Fingers two-thirds webbed, toes three-fourths webbed. Skin of back rough but without enlarged tubercles, skin on belly with very many small tubercles; these are largest and most abundant about the anal region, whence the series extends out on to the inner sides of the thighs for about half their length. Upper parts of head, body, thighs, shins, feet, and arms of a grayish ground color vermiculated and blotched with blue, in alcohol; green, in life; more ashy gray shows on the limbs than on the back. Throat white, belly and lower sides of hind limbs yellowish.

Allied to *Hyla* (*Hylella*) *nigromaculata* (Meyer).

Type. — No. 2434, Mus. Comp. Zoöl., a single specimen, about an inch and a half long, taken at Pom, north coast of Jobi (Japen) Island, Geelvink Bay, Dutch Papua, February, 1907. T. Barbour, collector.

This species is named for Major P. A. Ouwens, Curator of the Buitenzorg Museum, Java, who gave me a most kind hospitality, much assistance, and information.

Date Due